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ACQUISITION RESEARCH PROGRAM
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Is Electronic Life-Cycle Tracking of Aircraft Parts Degrading Readiness?

4 December 2013

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LT Mark Williams, USN

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14. ABSTRACT
The Naval Aviation Logistics Command Managed Information System (NALCOMIS), the current Navy and Marine Corps electronic tracking system for aircraft components, provides complete, up-to-date life-cycle information about aircraft and associated components to all maintenance agencies across the Naval Aviation Enterprise (NAE). By design, the system is meant to facilitate efficient receipt, repair, documentation, and transfer of all aircraft and components inducted into the maintenance cycle. However, many end users within the NAE still receive a significant volume of aircraft and associated components from higher echelon maintenance activities without current electronic life-cycle records entered in NALCOMIS. Consequently, components cannot be certified as ready for issue and utilized to revive non-mission-capable aircraft into full mission capable status. As a result, the Navy and Marine Corps incur significant costs, including decreased availability of air assets, degraded operational readiness, early retirement of aircraft components, and inefficient utilization of aviation maintenance administrative personnel. This report applies the Six Sigma define, measure, analyze, improve and control process approach to evaluate current procedures across the entire maintenance cycle and includes analysis of both quantitative and qualitative data in order to identify bottlenecks and inefficiencies. Recommendations are focused on cost reductions through overall process improvement and seek to minimize personnel-hour expenditures whereby aircraft availability and operational readiness can be increased.

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Abstract

The Naval Aviation Logistics Command Managed Information System (NALCOMIS), the current Navy and Marine Corps electronic tracking system for aircraft components, provides complete, up-to-date life-cycle information about aircraft and associated components to all maintenance agencies across the Naval Aviation Enterprise (NAE). By design, the system is meant to facilitate efficient receipt, repair, documentation, and transfer of all aircraft and components inducted into the maintenance cycle. However, many end users within the NAE still receive a significant volume of aircraft and associated components from higher echelon maintenance activities without current electronic life-cycle records entered in NALCOMIS. Consequently, components cannot be certified as ready for issue and utilized to revive non-mission-capable aircraft into full mission capable status. As a result, the Navy and Marine Corps incur significant costs, including decreased availability of air assets, degraded operational readiness, early retirement of aircraft components, and inefficient utilization of aviation maintenance administrative personnel. This report applies the Six Sigma define, measure, analyze, improve, and control process approach to evaluate current procedures across the entire maintenance cycle and includes analysis of both quantitative and qualitative data in order to identify bottlenecks and inefficiencies. Recommendations are focused on cost reductions through overall process improvement and seek to minimize personnel-hour expenditures whereby aircraft availability and operational readiness can be increased.

Keywords: NALCOMIS, Life-Cycle Tracking, DMAIC, Six Sigma, Aircraft Readiness

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I would like to thank the Army, Coast Guard, Marine, Navy, and international officers of the December 2013 NPS graduating class. Through your friendship, knowledge-sharing and professional collaboration, my educational experience was magnified to levels I never imagined possible. A special thanks to my MBA project partner, Lieutenant Mark Williams, whose knowledge and professional experience with our subject matter and quick-witted North Carolina humor kept me on task and laughing through the drudgery all the way to the finish line. Most importantly, I would like to express my deepest gratitude to my wife, Jen, and our beautiful children, Zoe and Gavin, for their continued love and encouragement throughout this endeavor. Although I was regrettably focused more on this project than on them for several months, they always treated me like I was husband and father of the year—for that, I am eternally grateful.

— Captain Eric Henzler

I would like to express my appreciation to my project partner and friends for the encouragement and direction they have provided to make this project a success. Moreover, I would like to thank my beautiful wife, Leslie, and our motivating team of kids, Alexander, Nicolas, Calista, and Sebastian, for the understanding and love throughout this process, and without whom any of this would have been possible.

— Lieutenant Mark Williams

We would also like to thank major contributors of information: U.S. Marine Corps Forces, Pacific, Fleet Readiness Center, Southwest and Marine Aviation Logistics Squadron 11 for their generous support, insight, and assistance during our project.

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Finally, we would like to especially thank professors Bryan Hudgens and Geraldo Ferrer for their time, support, and encouragement. Your guidance and mentorship was invaluable throughout the duration of this project.

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About the Authors

Major Eric J. Henzler enlisted in the Marine Corps in April 1993 and reported for recruit training to Marine Corps Recruit Depot, San Diego, CA, where he received the Military Occupational Specialty (MOS) Basic Finance Technician. In February 1994, he reported to the Finance Office, Headquarters Battalion, Marine Corps Logistics Base Albany, GA, where he served as military pay clerk, Travel NCO, and NCOIC of the Vendor Payment section.

In April 1997, Henzler reported to the Finance Office, Headquarters Battalion, Marine Corps Base Hawaii, where he served as NCOIC of the Travel section for twelve months. In May 1998, he was screened and selected as the MCBH commanding general's driver. During his tour as the driver, he applied for and was accepted into the Marine Enlisted Commissioning Education Program (MECEP).

In June 1999, Henzler reported to NROTC, University of Illinois Chicago (UIC) for duty as an MECEP student. Following his first year of school, he attended Officer Candidate School in Quantico, VA, where he graduated first in his platoon and third in the company. Following OCS, he reported back to UIC for the remaining three years of his college education, and in June 2001, was promoted to staff sergeant. Upon graduating with a Bachelor of Science degree in finance in May 2003, he was commissioned a second lieutenant.

In January 2004, Henzler graduated with "E" Company, Basic Officer Course 03-5 and reported to the Marine Corps Combat Service Support Schools (MCCSSS), Camp Johnson, NC, to attend the Ground Supply Officer Course. Following graduation in April 2004, he reported for duty with the Third Marine Regiment, where he served as the Assistant Regimental Supply Officer and supported exercises Talisman Saber, Tafakula, and Ulchi Freedom Guardian.

In January 2005, Henzler was assigned to 1st Battalion, 3d Marines as the Battalion Supply Officer, where he supported multiple pre-deployment training evolutions on the Big Island of Hawaii, mountain warfare training at MWTC Bridgeport, CA, and Mojave Viper at Twentynine Palms, CA. From December 2005 to June 2006, he deployed to Afghanistan in support of Operation Enduring Freedom.

In July 2006, Henzler reported to Headquarters and Service Battalion, U.S. Marine Corps Forces, Pacific and assumed the duties as the Battalion Supply

Officer, where he supported multiple PACOM Tier 1 Level Exercises throughout the Pacific AO, including Key Resolve, Cobra Gold, Talisman Saber, and Ulchi Freedom Guardian.

In June 2008, Capt Henzler was selected as the aide-de-camp to the deputy commanding general, U.S. Marine Corps Forces, Pacific. From June 2008 to September 2009, he supported the DCG, MARFORPAC in multiple areas around the Pacific Theater, including Australia, Guadalcanal, Guam, Iwo Jima, and the Republic of Korea.

In October 2009, he reported for duty as the supply and fiscal officer, Marine Tactical Air Command Squadron 38, Marine Air Control Group 38, Third Marine Aircraft Wing, and was additionally assigned as the company commander, Headquarters and Service Company, from February 2010 to May 2011. From June to December 2011, he served as an individual augment (IA) on the Joint Logistics (J4) staff at Special Operations Command Central in Tampa, FL.

In July 2012, Henzler reported to the Naval Postgraduate School, where he is currently working toward a Master of Business Administration degree in material logistics support management. On December 1, 2013, he was promoted to his current rank.

LT Mark Williams enlisted in the U.S. Navy on June 26, 1994, and attended boot camp at Great Lakes, Chicago, Ill. Following initial training, in December 1994 he went on to complete the Aviation Maintenance Administration course in Meridian, MS. His enlisted tours included the Aircraft Intermediate Maintenance Department (AIMD) Rota, Spain, and the Pukin' Dogs of VF-143 in Oceana, VA, where he was awarded Junior Sailor of the Year. Follow-on tours included the "Fleet Angels" of HC-2 and the Navy's H-3 Fleet Replacement squadron in Norfolk, VA, where he subsequently was selected for first class petty officer. In September 2004, he received orders to the USS *Harry S. Truman* and embarked on a deployment to the Fifth Fleet AOR. Following the completion of the deployment, AZ1 Williams was notified of his selection to chief petty officer and was pinned September 16, 2005. In February 2006, he was notified of his selection for advancement to ensign via the Limited Duty Officer Program and was commissioned in May 2007.

Upon completion of LDO indoctrination and Aviation Maintenance Officer School in August 2007, LT Williams reported to HSC-21 in San Diego, CA. During his tour in HSC-21, Williams served as the line division, assistant maintenance officer, maintenance material control officer, and detachment maintenance officer.

During his tour, he was deployed to Camp Buehring, Kuwait, where he led the maintenance effort for the Navy's only MEDEVAC unit. During this deployment, LT Williams was extended for a second deployment in the region and established initial MEDEVAC capabilities at Camp Basra, Iraq. Upon returning to San Diego, LT Williams completed his bachelor's degree from Saint Leo University in business administration. He subsequently completed one more deployment as the detachment maintenance officer before receiving orders to Fleet Readiness Center, Southeast (FRCSE).

LT Williams transferred to FRCSE in Jacksonville, FL, and served as the Support Equipment and Power Plants Division officer. During this tour, he applied and was accepted for lateral transfer into the Aviation Maintenance Division Officer community.

His personal awards include the Navy and Marine Corps Commendation Medal (two awards), Army Commendation Medal, the Navy and Marine Corps Achievement Medal (eight awards), and various other decorations. He is authorized to wear the Professional Aviation Maintenance Officer Warfare insignia.

He is married to his wife, Leslie, and they have four children: Alex, Nicolas, Calista, and Sebastian.

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List of Acronyms and Abbreviations

ALS	Automated Log-Set
AMSR	Aviation Maintenance and Supply Readiness
AMSU	Aeronautical Maintenance Screening Unit
AZ	Aviation Maintenance Administration
CM	Configuration Management
CNO	Chief of Naval Operations
COMNAVAIRFOR	Commander, Naval Air Forces
CPI	Continuous Process Improvement
D-level	Depot-Level Maintenance
FMC	Full Mission Capable
FRC	Fleet Readiness Center
I-level	Intermediate-Level Maintenance
MAF	Maintenance Action Form
MAW	Marine Aircraft Wing
MCAS	Marine Corps Air Station
MIM	Maintenance Instruction Manual
MMCO	Maintenance Material Control Officer
MO	Maintenance Officer
MSR	Module Service Record
NALCOMIS	Naval Aviation Logistics Command Managed Information System
NAMP	Naval Aviation Maintenance Program
NMC	Not Mission Capable
NTCSS	Naval Tactical Command Support System
OEM	Original Equipment Manufacturer
OIMA	Optimized Intermediate Maintenance Activity
O-level	Organizational-Level Maintenance
OMA	Organizational Maintenance Activity

OMAWHOLE	Optimized OMA NALCOMIS Wholesale Foundation Tier
OOMA	Optimized Organizational Maintenance Activity
PMIC	Periodic Maintenance Information Cards
RFI	Ready for Issue
SFF	Safe for Flight
SPAWAR	Space and Naval Warfare Systems Command
SRC	Scheduled Removal Component
T/M/S	Type Model Series
WIP	Work in Process

I. INTRODUCTION

On December 19, 2012, Commander, Naval Air Forces, Pacific issued *Aviation Maintenance Advisory (AMA) 2012-11*, which eliminated the requirement for all U.S. Marine Corps and U.S. Navy organizational, intermediate, and depot-level maintenance activities to maintain duplicate paper copies of certain aircraft maintenance forms (Commander Naval Air Forces, Pacific [COMNAVAIRPAC], 2012). Pursuant to the paperless initiative, maintenance activities were mandated to utilize automated log-sets (ALSs), also referred to as "log-sets"—electronic records containing the current and historical (or cradle-to-grave) maintenance life-cycle data for aircraft and life-limited components—as the sole source for life-cycle tracking.

In accordance with Commander Naval Air Forces Instruction (COMNAVAIRFORINST) 4790.2B, hereafter referred to as the *Naval Aviation Maintenance Program* (NAMP), "activities that have physical custody of naval aircraft, engines, and components shall maintain and update the ALS records" (Commander Naval Air Forces [COMNAVAIRFOR], 2012, p. 5-139). Compliance with this requirement is especially important during transfer of aircraft and components between depot, intermediate, and organizational activities and is absolutely critical for a component to be declared ready for issue (RFI), installed on an aircraft, and subsequently certified safe for flight (SFF).

Recently, U.S. Marine Corps Forces, Pacific's (MARFORPAC) Aviation Logistics Division reported an increase in aircraft and associated components arriving at various organizational-level units from either depot (D-level) or intermediate (I-level) maintenance activities without the associated ALS. Consequently, components cannot be certified RFI and utilized to revive non-mission-capable (NMC) aircraft into full mission capable (FMC) status, resulting in significant costs, including decreased availability of air assets, degraded operational readiness, early retirement of aircraft components, and inefficient utilization of aviation maintenance administrative personnel.

A. PURPOSE

The purpose of this study is to support the acceptance of and compliance with maintaining and updating ALSs through an analysis of current processes and procedures at each of the three maintenance levels of the NAE. Specifically, our study draws upon foundations of academic literature on business process improvement and an analysis of interview, survey, and empirical data to identify potential bottlenecks, pinpoint waste within the process flow, and determine root causes of variation both within and across organizations. We discuss the implications of our findings and provide recommendations for process improvement

and enterprise-wide compliance with electronic life-cycle tracking of aircraft and associated components.

The main objective of our research is to analyze current processes and determine the resultant cost of noncompliance with the NAMP requirement for maintaining and updating ALSs for aircraft and associated components. This research

- examines current process flows for ALSs at organizational, intermediate, and depot-level maintenance activities to determine inefficiencies and gaps in process flow;
- identifies the costs in personnel hours expended as a result of noncompliance with NAMP requirements for ALS maintenance; and
- evaluates barriers to compliance with NAMP policy regarding the maintenance and updating of ALSs.

B. BACKGROUND

In the guidance document *CNO's Sailing Directions*, the Chief of Naval Operations (CNO) stated, "Our primary mission is warfighting. All our efforts to improve capabilities, develop people, and structure our organizations should be grounded in this fundamental responsibility" (Chief of Naval Operations [CNO], 2012). Nested appropriately under this guiding principle, the Naval Aviation Vision stated, "The naval force needed today and in the future must be able to exert sea control, ensure access, deter conflict, defeat any threat, provide prompt striking power, and reassure allies and partners" (Naval Aviation Enterprise [NAE], 2012, p. i).

Integral to each of these objectives is Navy and Marine Corps Aviation, the lever by which precision and tailored combat effects are delivered in support of national defense. To that end, the current fiscally constrained and irregular warfare environment calls for an agile, flexible, and innovative aviation community focused on long-term sustainability through continuous process improvement and cost-conscious decision-making. Our research addresses process improvement and cost savings in the area of electronic life-cycle tracking of aircraft and associated components and is based on the define, measure, analyze, improve, and control (DMAIC) model commonly used within the Lean Six Sigma methodology for process improvement.

C. ORGANIZATION OF STUDY

In this report, we analyze current processes and utilization of electronic life-cycle tracking of aircraft and associated components and estimate costs of

noncompliance in personnel-hour expenditure. Chapter II presents a literature review of the business process improvement concepts used to formulate the research framework and provides an overview of the electronic life-cycle tracking process and associated stakeholders. In Chapter III, we explain the methods utilized to conduct the study; in Chapter IV, we define the problem in detail, and we illustrate our measurement of the problem in Chapter V. Chapters VI and VII provide the analysis of the research, discuss the implications of our findings, and outline actionable recommendations for process improvement and potential cost savings. Finally, Chapter VIII provides our final thoughts, limitations of the research, and recommendations for further study.

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II. LITERATURE REVIEW

A. INTRODUCTION

This chapter introduces AIR*Speed,* the NAE's program for cost-conscious readiness optimization, and then briefly discusses concepts and methodologies related to business process management, the theory of constraints (TOC), Lean, and Six Sigma, and finally, the chapter shows how each is directly applied to AIR*Speed.* Then we provide an overview of the electronic life-cycle tracking process, a sample ideal scenario, and a snapshot of key stakeholders. Finally, we review the current problem and explain how contributions from each business process management concept were utilized in the formulation of our study's framework.

B. AIRSPEED

Enterprise AIR*Speed* is the NAE's architecture for maximizing type/model/series (T/M/S) aircraft readiness while minimizing cost. The primary mission is "to transform the maintenance and supply chain into an integrated, reliable, demand-pull based replenishment system by training and mentoring Fleet Sailors and Marines in Continuous Process Improvement (CPI) methodologies and philosophies, institutionalizing business practices" (NAE, 2013).

Through the education and strategic implementation of CPI frameworks, including the TOC, Lean, and Six Sigma, Marines and Sailors as low as the tactical level are realizing significant operational-level effects on readiness and cost reductions across the NAE. According to Apte and Kang (2006), the five anticipated long-term benefits of AIR*Speed* include the following:

- Reduce total cost of naval aviation by reducing inventory, manpower and operating expenses.
- Support the Fleet Response Plan by providing aircraft ready for tasking (RFT).
- Integrate the maintenance and supply support system to provide seamless support to the fleet.
- Improve logistics and maintenance response by reducing cycle-time and the logistics footprint.
- Place ownership and accountability at the appropriate levels.

In the following paragraphs, we provide a brief description of the CPI methodologies employed within the AIR*Speed* program.

C. THEORY OF CONSTRAINTS

The TOC is a concept developed by Eliyahu M. Goldratt and is a *total system* improvement philosophy based on a cause-and-effect logic that enables a manager or management team to identify interdependencies within a system (Dettmer, 1997, p. xxi). Once interdependencies are identified, the TOC operates on the assumption that every system always has a constraint (often referred to as the bottleneck). Certainly, the objective for total system improvement revolves around eliminating or improving the constrained area, but it is extremely important to note that as one bottleneck is relieved, a different link in the process becomes the *new* constraint. Consequently, the TOC is a dynamic management tool that must be perpetually utilized as either the system or the operating environment changes.

In his book *Goldratt's Theory of Constraints*, Dettmer (1997) described the TOC as "a prescriptive theory that can tell you not only what is holding your system back, but also what to do about it and how to do it" (p. 11). He suggested that, by applying Goldratt's TOC, managers can answer three critical questions:

- *What* to change? (Where is the constraint?)
- What to change *to*? (What should be *done* with the constraint?)
- *How* to cause the change? (How is the change implemented?)

Dettmer cautioned that the aforementioned questions are *system* questions and should not be process focused. Although the questions and their answers will absolutely have an effect on processes, the key to successful transformation is at the total system level (Dettmer, 1997).

Perhaps the most common application of the TOC in AIR*Speed* is based on Goldratt's five focusing steps, which include the following:

1. **Identify the system constraint**. That is, which part of the system comprises the weakest link? Is it a physical constraint, or is it a policy?
2. **Decide how to exploit the constraint**. Here, *exploit* means maximizing the output (or improvement) of the constraint without overly expensive changes or upgrades.
3. **Subordinate everything else**. Essentially, this means adjusting the rest of the system to a setting (either up or down) that maximizes the performance of the constraint.
4. **Elevate the constraint**. This step is executed if, after Step 3, the constraint still exists and usually involves considerations of reorganization, major system overhaul, and commitment of substantial fiscal resources.

5. **Return to Step 1, but beware of inertia**. This step is executed when the initial constraint has been broken. It is important to prevent inertia from creating complacency, and instead, the search for the *new* constraint should be a continuous endeavor (Dettmer, 1997, pp. 14–15).

These focusing steps guide managers within the NAE to remain cognizant of their perpetual responsibility to maintain a total systems view where performance constraints are recognized and aggressively addressed so that the overarching goal of combat-ready naval aircraft is achieved and maintained.

D. LEAN

Lean can be defined as a set of principles that seeks to maximize value to the customer by enhancing process flow through focused minimization or elimination of waste (also known by the Japanese word *muda*). Stated another way, lean thinking "provides a way to specify value, line up value-creating actions in the best sequence, conduct these activities without interruption whenever someone requests them, and perform them more and more effectively" (Womack & Jones, 1996, p. 15).

Central to the lean concept is the narrow determination or precise definition of *value*. Essentially, value is directly tied to customer willingness to pay for a product or service. As such, once value has been adequately defined, processes are organized or set up to flow in a manner that maximizes value. Organization of process steps in this manner is also referred to as the *value stream*. Therefore, it follows that any activity within a value stream that does not directly contribute to the creation or enhancement of value is deemed waste and must be appropriately managed (Womack & Jones, 1996, pp. 29–38).

In his book *Lean Manufacturing: Tools, Techniques and How to Use Them*, Feld (2001) identified seven types of waste:

- **Excess production**—manufacturing an item or producing a service before it is actually required by the customer.
- **Over processing**—use of redundant systems, misunderstood quality requirements, or use of expensive, highly technical equipment when simple tools could get the job done.
- **Waiting**—downtime, component shortages, or long lead time.
- **Transportation**—poor utilization of space; excessive travel distance between processes eats up time and creates opportunity for decreased quality.

- **Motion**—excess movement due to multiple handling, low productivity, and operator idle time.
- **Inventory**—long changeover/set-up times, excess raw materials and work in process (WIP).
- **Defects**—poor process yield, high employee turnover, low employee involvement, limited process knowledge, inefficient communication.

The goal of a lean-thinking organization is to learn to identify these types of waste and eliminate them through the implementation of lean methodologies, summarized by Apte and Kang (2006) as follows:

- Focus on maximizing process velocity.
- Emphasize *value-stream mapping,* which centers on the separation of "value-added" from "non-value-added" work with tools to eliminate the root causes of non-valued activities and their cost.
- Recognize and attempt to eliminate eight types of waste/non-value-added work: defects, inventory, overproduction, waiting time, motion, transportation, processing, and human talent.
- Create workplace organization through the *Five S* methodology consisting of sort, straighten, sustain, sweep, and standardize.

Many of the lean methodologies described above are resident in the NAE's AIR*Speed* program and are perpetual refinement mechanisms serving the five essential elements of lean (U.S. Marine Corps Aviation Supply Officer Basic Qualification Course, personal communication, November 3, 2008):

1. Identify what creates value.
2. Identify the process (sequence) that creates the value.
3. Make the activities flow.
4. Let the customer pull the product or service requirement through the system.
5. Perfect the process.

E. SIX SIGMA

Six Sigma is a business process philosophy geared towards maximizing customer satisfaction (or value) through a relentless focus on eliminating variation or defects within a specific product or service. The Six Sigma concept was first introduced at Motorola in 1982 as a set of analytical tools to reduce costs and improve quality and has since been championed by other Fortune 500 companies

such as General Electric, Polaroid, DuPont, Ford Motor Company, and American Express (Stamatis, 2004).

Statistically speaking, Six Sigma is actually a reference to the Greek letter sigma (σ), commonly used to denote the standard deviation from the mean. In the context of the Six Sigma methodology, σ can be interpreted as a measure of variation within a process that in turn causes variation (or defects) in the end product or service. Six Sigma refers to a process almost completely free of variation and represents quality of the highest order. Placed in a numerical context for comparison, ±4 σ, the standard many companies currently employ, results in a 99.38% long-term yield (with approximately 10% of revenue lost to defects). When a ±6 σ philosophy is implemented, an organization may achieve a 99.99966% long-term yield with near-perfect quality at just 3.4 defects per one million opportunities (DPMO; Stamatis, 2004).

Within the AIR*Speed* construct employed across the NAE, a Six Sigma influence is immediately recognized and follows these basic guiding principles, as described by the instructors of the Aviation Supply Officer Basic Qualification Course (U.S. Marine Corps Aviation Supply Officer Basic Qualification Course, personal communication, November 3, 2008):

- genuine focus on the customer;
- data- and fact-driven;
- process focus, management, and improvement;
- collaboration without boundaries; and
- drive for perfection.

Central to the successful implementation of Six Sigma across the NAE is the full engagement of all personnel, from the flag officer level down to the most junior Marine or Sailor. The Six Sigma philosophy is a mindset for continuous improvement that must be ingrained across all levels in the organization and provide the flexible feedback loop required to ensure that no ideas for improvement go unnoticed or unexplored.

Probably the most common and widely used model within the Six Sigma philosophy is the *define, measure, analyze, improve, and control* (DMAIC) model. Just as many Fortune 500 companies have employed the DMAIC model, the NAE has also developed its own variation under the AIR*Speed* philosophy. Following is a brief description of each step in the model as taught at the Aviation Supply Officer Basic Qualification Course (U.S. Marine Corps Aviation Supply Officer Basic Qualification Course, personal communication, November 3, 2008). A graphical representation of the process can also be viewed in Figure 1.

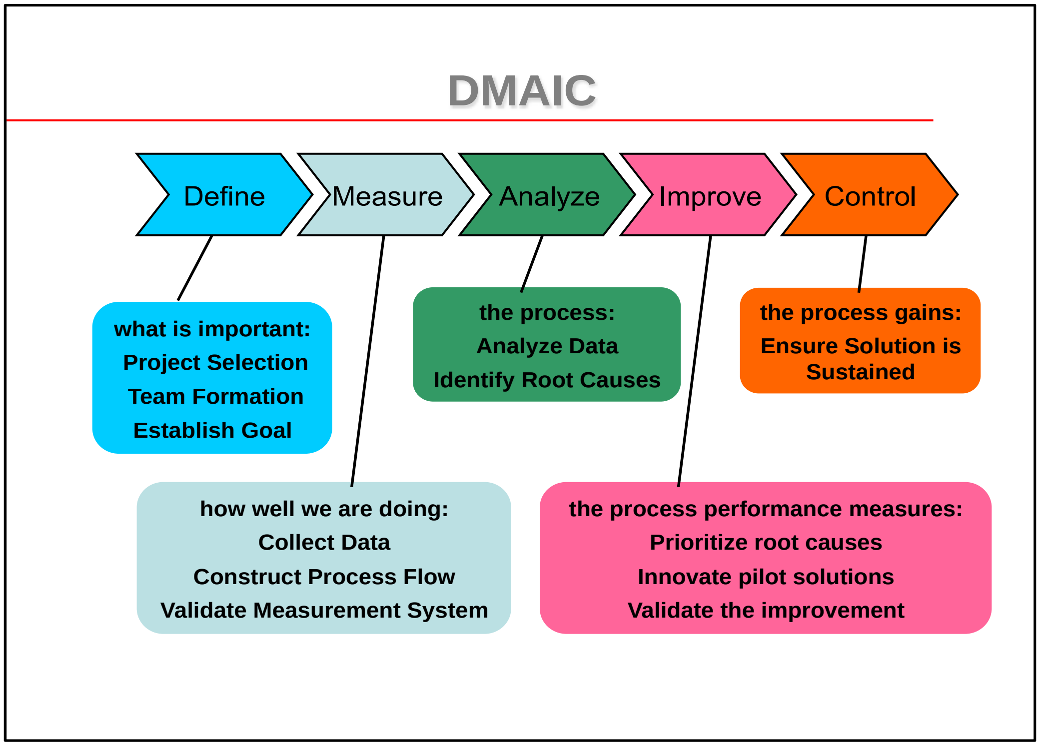

Figure 1. DMAIC Process
(U.S. Marine Corps Aviation Supply Officer Basic Qualification Course, personal communication, November 3, 2008)

1. Define

During this initial phase of the process, the foundation from which all other steps will be executed is molded. Specifically, team member selection occurs, and specific roles and responsibilities of each member are assigned. Once team members are assigned, the *customer* is defined, and an assessment of what is most important to customer satisfaction (value) is made. Next, the current process for delivering the product or service to the customer is mapped using tools such as cause-and-effect diagrams, physical process flow maps, or simple process observation. Based on the documentation of the current process, the project scope is defined to ensure that the assigned team has the appropriate resources and area of control to complete the project. Finally, a project goal and plan of action and milestones (POAM) is established and disseminated to all team members.

2. Measure

Measuring is the second step in the model and is primarily focused on the collection of data used to determine the variation within a process. During this step, team leaders determine the type of data that will be most useful, establish a data collection plan, and decide how the data (once collected) will be measured. Common tools used within this step include physical process flow maps, value-

stream mapping, and waste analysis, which each contribute to the validation of the proposed data measurement system and facilitate entry into the analysis phase.

3. Analyze

The analyze phase begins with an in-depth assessment of the data collected during the previous step. The primary focus during this phase is to validate assumptions regarding root causes (or improvement opportunities) made during problem measurement and to identify any gaps in the data collection that may require additional information. The key output of the analysis phase is the correct identification of root causes so that the problem statement can be refined, if required, and improvement opportunities in the next phase can be properly targeted.

4. Improve

Once the analysis is conducted and clearly defined improvement objectives are identified, team members enter the improve phase in the process. In this step, team members prioritize improvement opportunities (if multiple opportunities exist), brainstorm and develop pilot improvement initiatives, evaluate the potential impact of each, and select the alternatives that maximize customer value. Through the use of value-stream mapping, *as is* process maps are compared to *should be* process maps to validate the true effects of proposed improvements.

5. Control

The final step in the DMAIC model is the control phase. Although all stages in the process are important, this step is critical to sustaining the improvements to customer value that were implemented and validated during Step 4. Given the resistance to change often resident in many organizations, it is vitally important to establish mechanisms for safeguarding performance gains. Some methods commonly utilized include revision of standard operating procedures, establishment of new performance metrics, and assignment of quality control officers to monitor compliance.

F. ELECTRONIC LIFE-CYCLE TRACKING PROCESS OVERVIEW

The *NAMP* outlines the electronic record transfer and receipt process for Navy and Marine Corps aircraft and life-limited components. In the most general terms, the process involves three key elements: an information system, records, and personnel.

Central to the process is the Naval Aviation Logistics Command Management Information System (NALCOMIS). As defined in the *NAMP*, NALCOMIS is

> a modern, real time, on-line responsive computer based automated Management Information System (MIS) that allows Navy and Marine

> Corps aviation maintenance unit personnel to record flight and maintenance actions, quickly obtain timely and accurate aircraft and equipment maintenance status, scheduled maintenance requirements and additional information required in their day-to-day management and decision making process. (COMNAVAIRFOR, 2012, p. A-50)

Essentially, NALCOMIS serves as an enterprise-wide management system whereby configuration management of aircraft and life-limited components is achieved across the organizational, intermediate, and depot-level maintenance activities throughout the fleet. Through NALCOMIS, complete, accurate, and current life-cycle information on aircraft, individual components, and support equipment is possible via a multi-tiered server configuration and data storage repository, which enables the improvement of information quality of all records for the end user. An overview of the NALCOMIS data collection system can be seen in Figure 2.

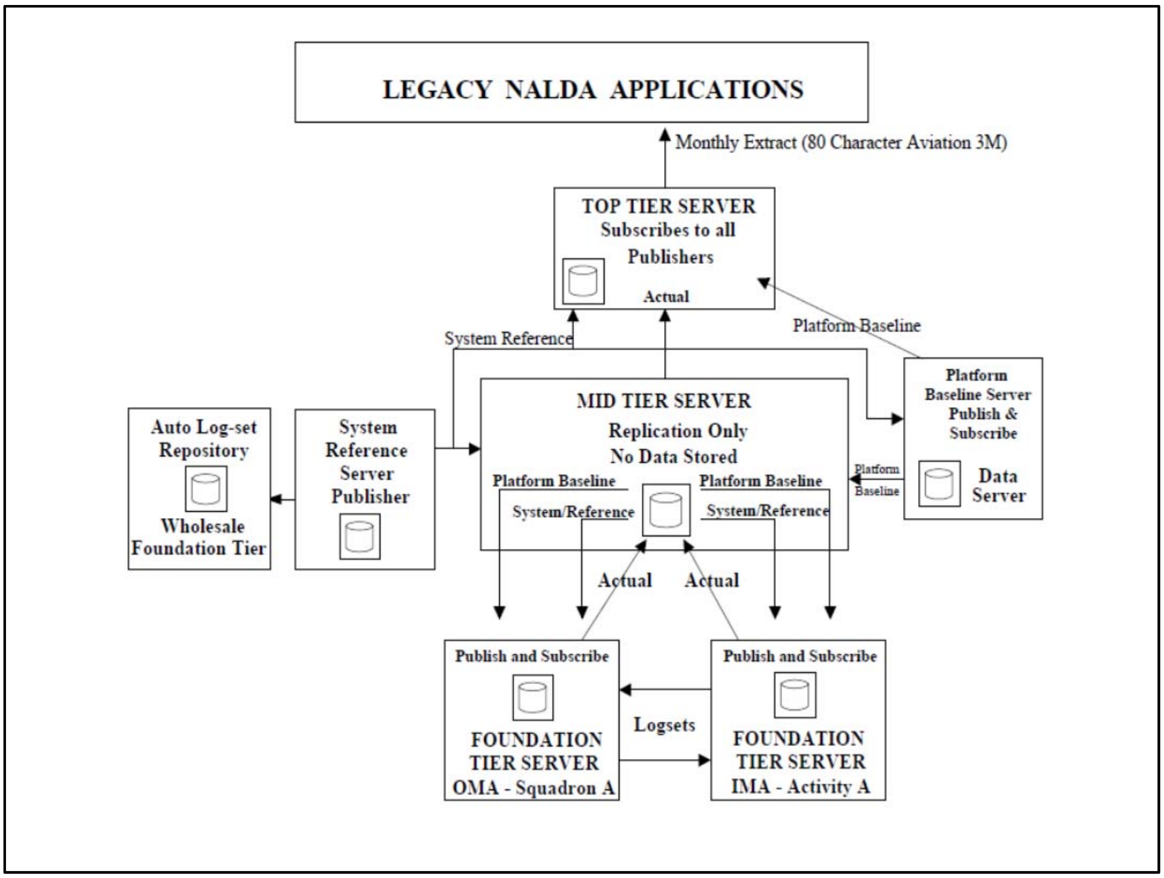

Figure 2. Naval Tactical Command Support System (NTCSS) Optimized Organizational Maintenance Activity (OMA) NALCOMIS Replication (COMNAVAIRFOR, 2012)

The process of information transfer utilizing the NALCOMIS system allows users at each level of the NAE to effectively and efficiently manage the life-cycle tracking of all aviation maintenance-related items. Defining the process aircraft or

component implementation into NALCOMIS starts at the mid-tier level with the creation of the log-set and the applicable baseline for the affected item. Subsequently, the newly created log-set shell will be passed on to the end users upon successful completion at the mid-tier level by Space and Naval Warfare Systems Command (SPAWAR) and therefore will be available for the organizational and intermediate levels of maintenance, known as the foundation tier servers.

Throughout this application process that includes life-cycle tracking of affected items, an automated replication process occurs daily to the top tier servers to ensure that current and historical data are being maintained in case of a future need to provide the data downstream to the end users. Replicating the data from end users is critical in order to maintain a contingency plan for all applicable tracked items. As detailed in Figure 2, the flow of log-sets should be a seamless process between users at the organizational and intermediate levels, with a number of back-up servers placed at SPAWAR and Naval Air Systems Command (NAVAIRSYSCOM) to ensure proper replication is occurring and system support is available when necessary.

The second element within the process, the records, are known as auto log-sets (ALSs) and defined in the *NAMP* as

> records which provide a detailed and separate view of the different historical maintenance tasks and usage, miscellaneous history, repair/rework, and excesses. Additionally, they are the administrative means of providing managers with aircraft/equipment age, status, modification, configuration, and historical data to plan, maintain, and operate aircraft and equipment. (COMNAVAIRFOR, 2012, p. A-4)

If NALCOMIS is the highway system that propels information across levels in the maintenance chain, ALSs are the vehicles that carry the information. Each individual aircraft and life-limited component has a unique ALS that contains the complete life-cycle information for that specific item. As maintenance actions at any level are executed on aircraft or components, log-sets are updated in NALCOMIS, and full data integration and information sharing across the maintenance enterprise are achieved. The challenge, as with any ERP system, is that the information is only as good as the timely and accurate input of the data.

Maintaining the automobile analogy mentioned previously, the final element in the process is personnel, who can be viewed as the individuals responsible for packing up the trunk prior to departure. Specifically, these personnel are directly responsible for keypunching and certifying the log-set data in NALCOMIS as maintenance actions occur in the process. In general, personnel authorized to enter transactions into NALCOMIS that, in turn, automatically update the log-set, include Navy and Marine aviators and enlisted Marines and Sailors trained as maintenance

administrators (AZ) and maintenance technicians, as well as their respective civilian contractor equivalents at the depot-level activities. Personnel generally authorized to certify log-set transactions via the commanding officer's delegation of authority include Navy and Marine Corps officers trained as maintenance material control officers, qualified senior enlisted Marines and Sailors, and civilian contractor equivalents at the depot-level activities.

G. SAMPLE IDEAL SCENARIO

The following typical scenario is provided to illustrate the ideal intended process flow of electronic life-cycle information for aircraft and life-limited components across the NAE: Following a training mission, an F/A-18 aircraft returns to a squadron with maintenance issues. The pilot initiates a maintenance action form (MAF) in NALCOMIS and debriefs the maintenance technicians on the specific issue that occurred in flight to expedite their troubleshooting actions. Technicians complete troubleshooting of the system, determine the component to be faulty, and subsequently remove the component from the aircraft. Immediately upon removal, the maintenance technician updates the log-set for the faulty component in NALCOMIS and physically transfers custody to supply for induction into the repair cycle at the intermediate-level (I-level) repair facility.

Once the faulty component is physically received at the I-level, the Aeronautical Material Screening Unit (AMSU) reviews the log-set and determines the appropriate work center to conduct the repair (I-level maintenance cannot begin until the log-set for the faulty component is verified as properly updated in NALCOMIS). Once the log-set is verified, the appropriate work center executes the repair and continually updates the log-set in NALCOMIS, indicating the full spectrum of specific maintenance actions conducted.

Following repair, the now RFI component is physically transferred back through the AMSU to the organizational unit supply section for future fulfillment of an aircraft requisition for the component. Upon physical receipt of the component, supply personnel verify the log-set in NALCOMIS to ensure it was properly updated by the I-level maintenance activity prior to transfer. The repaired component cannot be installed on an aircraft until the log-set has been verified as properly updated in NALCOMIS.

H. STAKEHOLDERS

Utilizing Freeman's (1984) stakeholder management framework and philosophy during this process, key stakeholders within the organization were identified (pp. 52–80). At the macro-level, stakeholders potentially affected by this problem include combatant commanders and assigned forces dispersed throughout the world that depend on high operational readiness and availability of air assets to

conduct direct action, power projection, reconnaissance, and logistics support missions. Drilled down a notch, stakeholders within the NAE encompass all Navy and Marine Corps aviation and aviation support units across the organizational, intermediate, and depot levels. The stakeholder population, which our study targeted, includes

- Naval Aviation Enterprise;
- United States Marine Corps Forces, Pacific;
- I- and D-level maintenance activities from the Fleet Readiness Center (FRC) Southwest at North Island, CA; and
- Organizational squadrons from the Third Marine Aircraft Wing in Miramar, CA.

1. Naval Aviation Enterprise

The impetus for what is now the NAE can actually be traced all the way back to the early 1990s when aviation units were experiencing significant variance in readiness levels across the fleet. The prevailing culture was such that squadrons would attain the highest possible readiness levels prior to a deployment, then dip down to borderline unacceptable readiness levels when not deployed and be forced to spend irresponsible levels of resources to drive readiness levels back up for the next deployment rotation. Over time, as resources (flight hours, aircraft, and personnel) decreased, total cost to Naval Aviation steadily increased and ultimately degraded the long-term procurement and fiscal sustainability of Naval Aviation (NAE, 2013).

In response to diminishing resources that inevitably pushed procurement of new aircraft and equipment further into the future, the Navy understood the imperative of maintaining and maximizing the effective use of legacy systems as long as possible. To that end, from 1993 to 2001, the Navy established several programs aimed at reduced cost through partnership and process improvement, which included air boards, the Naval Aviation Pilot Production Improvement Program (NAPPI), the Aviation Maintenance and Supply Readiness Group (AMSR), and the Naval Aviation Readiness Integrated Improvement Program (NAVRIIP; NAE, 2013).

In 2004, the NAE as it exists today was formed out of best practices and lessons learned from all previous process improvement efforts. The mission statement developed for the NAE is to advance and sustain Naval Aviation warfighting capabilities at an affordable cost today and in the future.

2. U.S. Marine Corps Forces, Pacific

United States Marine Corps Forces, Pacific (MARFORPAC) is the Marine Corps' largest field command, comprised of approximately 86,000 Marines and Sailors and roughly two thirds of the Marine Corps' combat power with bases, stations, and deployed forces spanning an area from Yuma, AZ, west to Okinawa, Japan. Inherent in its force structure, MARFORPAC forces form Marine Air Ground Task Forces (MAGTFs) of varying size, including Marine Expeditionary Forces (MEFs), Marine Expeditionary Brigades (MEBs), Marine Expeditionary Units (MEUs), and the Special Purpose Marine Air Ground Task Forces (SPMAGTFs; United States Marine Corps [USMC], 2013).

For the purpose of our research, we focused on the Aviation Combat Elements (ACEs) of the two MEFs within MARFORPAC, I MEF and III MEF, and specifically on operational-level squadrons from both the First Marine Aircraft Wing (MAW) in Okinawa, Japan, and the Third MAW in Miramar, CA. Through the assistance of the Aviation Logistics Division at MARFORPAC, data collection regarding utilization of electronic life-cycle tracking of aircraft and life-limited components was solicited and successfully obtained from eight organizational units.

3. Fleet Readiness Center Southwest

Fleet Readiness Center Southwest (FRCSW) is located at Naval Air Station (NAS) North Island in San Diego, CA, and its mission is to provide top quality products and services at the best value in the fastest time. Utilizing a combination of management systems. including Lean, TOC, and Six Sigma, FRCSW possesses maintenance and repair capability for over 11,700 unique components of Navy and Marine Corps aviation platforms, including F/A-18 Hornets, E-2 Hawkeyes, C-2A Greyhounds, SH-60 Seahawks, Marine Corps AH-1 Cobra attack helicopters, UH-1 Huey general purpose helicopters, CH-53 Sea Stallion heavy lift helicopters, AV-8B Harrier VTOL aircraft, and the EA-6B Prowler electronic warfare aircraft (Naval Air Systems Command, 2013).

In addition to FRCSW's main industrial complex at NAS North Island, it also operates permanent depot-level maintenance sites at Marine Corps Air Stations (MCAS) Miramar, CA, and Yuma, AZ; Marine Corps Base Camps Pendleton, CA, and Kaneohe Bay, HI; and Naval Air Weapons Station Point Mugu, CA, and Naval Base Point Loma, CA (Naval Air Systems Command, 2013). For the purpose of our research, we conducted site visits to the main depot repair facility at NAS North Island and the MCAS Miramar facility in order to interview uniformed subject-matter experts (SMEs) and civilian depot artisans to ascertain current processes and pinpoint potential problem areas regarding the utilization of electronic life-cycle tracking of aircraft and life-limited components.

4. Organizational Squadrons From MCAS Miramar

Due to their requests to remain anonymous, the specific organizational units we visited and interviewed at MCAS Miramar are not disclosed in this report.

I. CURRENT PROBLEM

Given that NALCOMIS was designed to enhance ALS information sharing, reduce redundant data entry, and improve the quality of component life-cycle information across the NAE, and despite the fact that FRC maintenance activities are required by COMNAVAIRFOR directives to update electronic log-sets in NALCOMIS prior to transfer, many organizational-level units have aircraft and aircraft components returning to their squadron in an RFI status without the ALS updated in NALCOMIS.

Consequently, squadron maintenance administrators must conduct extensive research to retrieve the log-set for aircraft or a specific component before installation of the component may occur and the aircraft may be certified SFF. Research time (in man-hours) for the retrieval of a log-set can range from four hours to several days, depending on factors including knowledge and experience of the maintenance administrator, location of the aircraft (deployed or garrison), last confirmed log-set update in NALCOMIS (resident in the data repository), and last known physical custodian of the component.

In severe cases, log-set research and retrieval attempts via worldwide search of the master wholesale NALCOMIS data repository, known as Operational Maintenance Activity WHOLE (OMAWHOLE), are met with negative results. As a result, maintenance technicians must completely rebuild the log-set shell for the specific component. Including research time prior to the reconstruction of the log-set, this process may take weeks.

The end result in both cases is increased man-hours expended by the maintenance technicians and other aviation maintenance personnel, reduced aircraft availability for the organizational unit, and decreased operational readiness across the enterprise.

J. OUR RESEARCH

This study examines the fleet-wide utilization of electronic life-cycle data within NALCOMIS during the transfer–receipt process and measures its effects on cost (man-hours), aircraft availability, and operational readiness across the NAE. In our analysis, we use the Lean Six Sigma framework for identifying and eliminating variation in business and maintenance processes. Specifically, we tailor the DMAIC methodology within Lean Six Sigma to achieve sufficient granularity into the root

cause and magnitude of the issue and determine targeted improvement actions that are realistic and sustainable.

III. METHODOLOGY

This research analyzes current processes and utilization of electronic life-cycle tracking of aircraft and associated components and estimates costs of noncompliance in personnel-hour expenditure. The study is based on multiple U.S. Marine Corps and U.S. Navy units that were asked to participate in research initiated by U.S. Marine Corps Forces, Pacific and sponsored by the Acquisition Research Program (ARP) at the Naval Postgraduate School (NPS) in Monterey, CA. Anonymous online surveys were distributed to all hands, in conjunction with on-site face-to-face interviews with key leaders, both of which comprised the research. Twenty usable anonymous surveys were returned, six incomplete surveys were returned, and 10 on-site interviews were conducted with key decision-making leadership personnel.

The online anonymous survey and on-site interview questions were designed to explore current processes and utilization of electronic life-cycle tracking of aircraft and associated components and estimate costs of noncompliance in personnel-hour expenditure across the surveyed population. The survey and interview questions were reviewed and approved by the Department of the Navy (DON) Internal Review Board (IRB), the USMC IRB, and selected NPS professors before execution. A copy of the survey and interview questions can be viewed in Appendix A of this report.

The methodology we used in this research project consisted of the following steps:

1. Conducted a literature review of books, peer-reviewed professional journals, websites and other electronic media, and various other resources from the Dudley Knox Library.
2. Conducted a thorough review of current Naval Aviation policies regarding the mandatory utilization of electronic life-cycle tracking of aircraft and life-limited components.
3. Conducted surveys targeting U.S. Navy and Marine Corps officers and enlisted, DoD civilian employees, and contractors serving in billets within the aviation maintenance community at the organizational, intermediate, and depot levels to collect information regarding the utilization of electronic life-cycle tracking of aircraft and life-limited components. Specific billets include depot-level artisan, production officer, maintenance material control officer (MMCO), maintenance AZ, maintenance chief, maintenance technician, expeditor, and supply.

4. Executed data collection at select organizational squadrons to ascertain the cost in man-hours, aircraft availability, and operational readiness resulting from aircraft and components received as RFI but without the required electronic record, the ALS.
5. Executed a site visit to FRCSW at NAS North Island in San Diego, CA, to conduct interviews with SMEs at the D- and I-level repair facilities.
6. Executed a site visit to select operational squadrons at Marine Corps Air Station Miramar in San Diego, CA, to observe current processes for receipt and transfer of electronic life-cycle data for aircraft and life-limited components.
7. Conducted a review and analysis of the data and survey results collected.
8. Prepared a summary of findings and provided recommendations.

IV. DEFINING THE PROBLEM

A. PRESENT STATE

Following initial observation, the baseline problem in the most simple terms is a decreased number of aircraft ready for tasking (RFT), a problem caused by missing or incomplete electronic log-set information. The subsequent immediate action to rectify a situation created by the baseline problem—increased personnel hours—is in itself an undesired effect and thus also considered a problem. Although aircraft RFT is a readiness metric most directly affecting squadron operations at the organizational level (O-level), updating and transferring electronic log-sets occurs at the O-, I-, and D- levels. Consequently, we investigated current operating procedures at all three levels to ascertain the scope and magnitude of the problem and pinpoint any root cause. In order to frame our investigation, we created a fishbone diagram to help us brainstorm potential contributors and problem commonality across all three levels.

B. FISHBONE DIAGRAM

To develop the fishbone diagram, we conducted face-to-face interviews with officers and with enlisted and civilian contractor personnel from the O-, I-, and D-levels who are intimately involved in the receipt, update, and transfer of electronic log-sets. Additionally, we administered electronic surveys to multiple O-level squadrons in which we asked open-ended questions in order to gain a grassroots assessment of the breadth and depth of the problem.

Although the fishbone diagram itself does not define the problem, it does provide valuable insight into the potential root cause(s) of the problem (Adams, 2003 pp. 89–93). As shown in Figure 3, we organized the diagram into six categories—machine, manpower, management, method, material, and measurement—which we discuss in the following paragraphs.

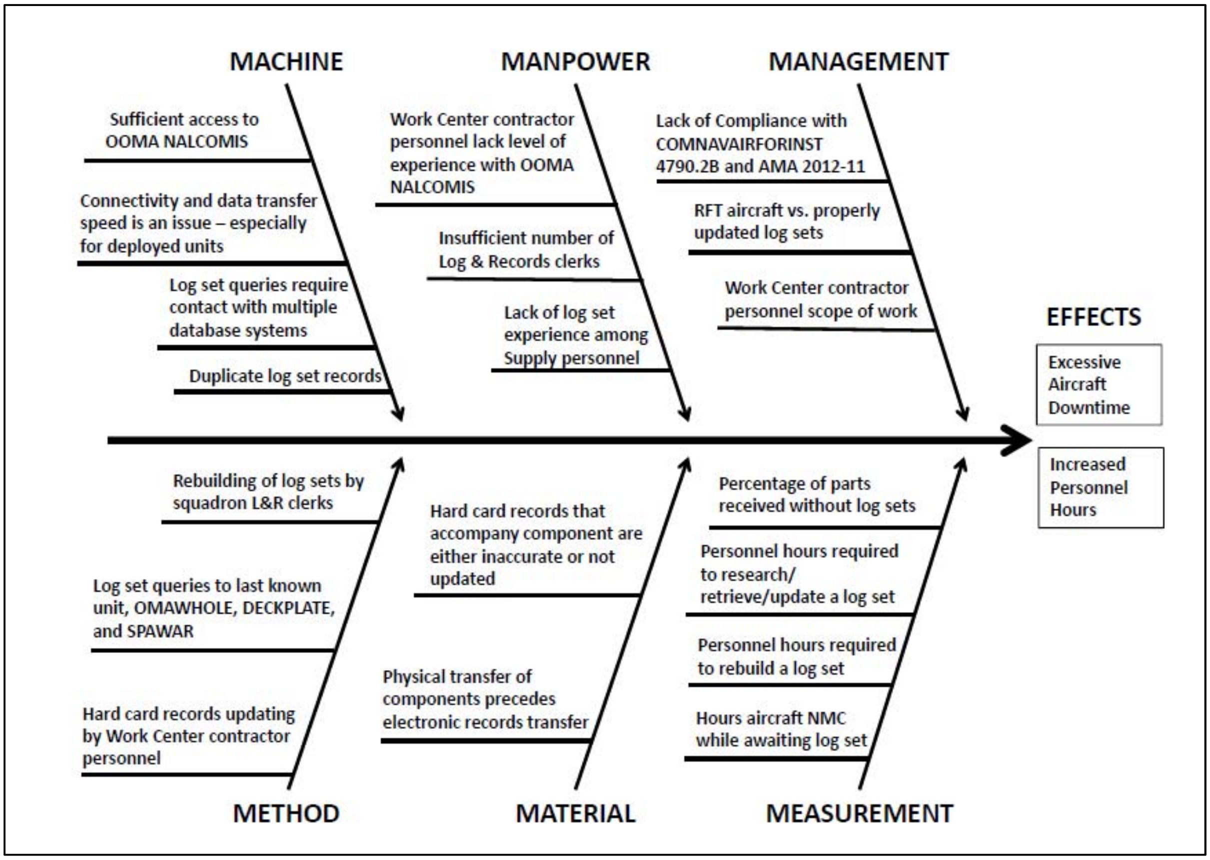

Figure 3. Fishbone Diagram

1. Machine

The first question regarding machinery asked in every location we interviewed was whether they had Optimized Organizational Maintenance Activity (OOMA) NALCOMIS capability, as this is the most up-to-date aircraft life-cycle information system in use across the NAE. In all the activities we interviewed, OOMA NALCOMIS was available on a sufficient number of workstations to facilitate the timely updating of log-set information. It was also reported that OOMA NALCOMIS capability is available to units in a deployed environment, including Afghanistan.

In the event an aircraft component arrives at an O-level activity without the electronic log-set, the receiving unit normally conducts a database query in an attempt to retrieve the log-set. The query process is hierarchical, starting with attempts to contact the last known unit in physical custody of the asset, progressing to a search of the OOMA NALCOMIS wholesale foundation log-set repository known as OMAWHOLE, and finally ending with a search of the top tier server. Multiple factors affect the speed with which a query is answered, including Internet connectivity, bandwidth speed, and availability of customer service personnel to assist at the top tier level. The longer a complete query cycle takes, the longer the aircraft remains in a non-RFT status.

Following a complete log-set query cycle, if the current electronic log-set cannot be retrieved, the O-level activity reconstructs the log-set in OOMA NALCOMIS using all information on the hard card paperwork and any other piecemeal information that can be obtained via database repository searches. The amount of time required to reconstruct a log-set was reported to range from approximately one hour to multiple days. Additionally, second- and third-order effects of reconstructing log-sets were reported to include flight hour penalties to life-limited components (resulting in premature retirement and fiscal waste) and duplicate records populating OOMA NALCOMIS and other data repositories.

2. Manpower

One common manpower issue reported by 100% of interview respondents was T/M/S maintenance work center personnel lacking the OOMA NALCOMIS knowledge and experience to properly update electronic log-sets. Despite the fact that OOMA NALCOMIS was readily available for use at O-, I-, and D-level activities, there were many instances reported in which contractor personnel (specifically, those personnel actually repairing the aircraft components) did not have the requisite knowledge to record maintenance actions in OOMA NALCOMIS and instead simply annotated repairs executed on the hard-copy MAF. Consequently, the electronic log-set was either subsequently updated in OOMA NALCOMIS by a uniformed service member, or the component was transferred without an updated electronic log-set and accompanied by only the hard-copy paperwork.

In cases where the onus to update an electronic log-set or completely reconstruct it was transferred to the O-level activity, four out of 10 units reported an insufficient number of Logs and Records personnel to adequately handle the workload during a typical length workday. Instead, existing Logs and Records personnel with the requisite OOMA NALCOMIS knowledge and experience were subjected to increased work hours in order to rectify missing or incomplete log-set information while still accomplishing their day-to-day workload. Additionally, it was noted that supply personnel in some units lacked experience in screening and validating log-sets for components received, which tended to further exacerbate the problem by perpetuating stock rooms filled with components either completely lacking an electronic log-set or containing log-sets that were not current and updated.

3. Management

At the most basic level, compliance with electronic log-set policy and procedures as outlined in the COMNAVAIRFORINST 4790.2B and *AMA 2012-11* requires managerial oversight and vigilant enforcement. However, our research indicated that supervisors from the unit commander down to the maintenance officer

(MO) must balance the obligation to maximize RFT aircraft and meet flight schedules with the requirement to properly manage the electronic log-sets of components.

For example, an O-level squadron with an aircraft that is NMC because a required component has been received but not installed due to a missing or incomplete log-set must decide on an appropriate corrective action. The squadron may choose to execute the complete log-set query process and wait until the log-set is received before installing the part and certifying the aircraft SFF. Or it may choose to forego the full log-set retrieval process and simply reconstruct the electronic log-set in order to more quickly revive the NMC aircraft to an SFF, RFT status.

In certain situations (such as combat), commanders may accept the risk and costs associated with reconstructing a log-set in the interest of maximizing RFT aircraft. However, the second- and third-order effects of such decisions, namely the potential flight hour penalty and early retirement of the component, as well as the duplication of the log-set record, must be carefully considered before deciding to forego the full-cycle log-set retrieval process.

Another contributory factor which management has the capacity to shape is the scope of work for civilian T/M/S work center personnel contracted by the U.S. government to execute component and aircraft maintenance actions at the I- and D-levels. If the use of OOMA NALCOMIS, specifically the electronic updating of log-sets, was included in the scope of work of these contracts and enforced by I- and D-level management personnel, the magnitude of components received without an updated log-set would very likely be significantly reduced.

4. Method

The basic methods for querying or reconstructing a log-set were common and seemingly accepted across all activities interviewed or surveyed and are consistent with the process described in the *Machine* section. Each unit interviewed or surveyed had at least some standardized and publicized process for handling components with missing electronic log-sets. However, eight out of 10 units seemed to have specific key personnel who knew exactly what to do when these issues arose and several additional personnel who seemed to lack the confidence and expertise required to execute the process with speed and efficiency.

Despite the paperless record transition mandated by *AMA 2012-11*, it is evident that handwritten updating of paper copy records is still heavily ingrained in the aircraft maintenance culture, especially at the I- and D-levels among civilian work center personnel. Although hard-copy maintenance records can provide a source document from which to update or reconstruct an electronic log-set, there is no

guarantee that the hard-copy record will physically accompany the component when transferred.

5. Material

Nine out of 10 units interviewed reported issues regarding material in which the physical transfer and receipt of the component was completed before the electronic transfer of the log-set was executed (assuming the log-set was, in fact, updated and transferred). Understandably, the log-set cannot be fully updated and transferred until all required maintenance actions on a component are completed. Likewise, it is conceivable a component repaired by a Marine Aviation Logistics Squadron (MALS) may be physically transferred to an O-level squadron located on the same flight line before the electronic log-set transfer is completed. However, in situations where a component is repaired and shipped to an activity that is geographically dispersed, it is reasonable to expect a log-set to be fully updated and transferred immediately following maintenance action completion, thus decreasing or even eliminating the lag in log-set transfer time.

Another common material issue reported by all the activities interviewed and surveyed is that hard-copy maintenance records accompanying the component shipment are often inaccurate, not updated, or not present in the shipment. Certainly, this would not be problematic if the electronic log-set was updated and transferred as required, but in many cases the hard-copy paperwork becomes the impetus for reconstructing the life-cycle history of the component in the case of a missing log-set. Inaccurate or missing hard-copy paperwork negates a valuable starting point from which a complete log-set query cycle may be launched. As a result, log-set retrieval time is extended, life-limit penalty to the component may be greater, and the aircraft remains NMC for a longer period.

6. Measurement

There are several metrics to measure the effects of noncompliance with electronic life-cycle tracking of aircraft components. From an operational readiness perspective, *the* metric to consider is the time an aircraft is NMC due to a missing or incomplete log-set. This is the metric of focus in this report. When exploring the efficient use of personnel work hours, and by extension, the minimum number of personnel required in a Logs and Records section, suitable metrics are the time required to execute the query cycle for a log-set and the total time required to reconstruct a log-set. These metrics are also presented and analyzed in our research.

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V. MEASURING THE PROBLEM

A. ESTABLISHING A BASELINE

In order to properly measure the problem, we established a common understanding of the instructions and directives that govern the process of updating, transferring, and receiving electronic log-set records for aircraft and life-limited components. Additionally, we created process maps to include the human and automated steps required to complete aircraft and component maintenance actions at the O-, I-, and D-level activities. Utilizing this measurement technique, we were able to isolate the myriad steps in the processes in order to help pinpoint where the drivers of the root problem reside.

B. MAINTENANCE FRAMEWORK

All maintenance actions performed within the NAE are subject to a standardized hierarchy consisting of three levels of maintenance: organizational, intermediate, and depot (Commander Naval Air Forces [COMNAVAIRFOR], 2012, p. 3-1). Accordingly, the different levels of maintenance fall into a work breakdown structure that best aligns to the various levels and capabilities of support personnel organic to each level and that ensures maintenance tasks are consistent with job complexity and the range of work to be performed. Tasks performed by maintainers and artisans vary from removing and replacing an aircraft component at the O- or I-level to completely overhauling the avionics system of an F/A-18 at the D-level.

Maintenance for each T/M/S aircraft is governed by a unique maintenance instruction manual (MIM), which clearly delineates the appropriate level of maintenance for each maintenance action. Additionally, maintenance for support equipment (SE)—mobile or fixed equipment required to support the operation and maintenance of an aircraft—is regulated by an assigned manual distinguished by the model of equipment awaiting repair, rework, and inspection.

C. ORGANIZATIONAL-LEVEL MAINTENANCE

O-level maintenance activities support flight operations of their squadrons' assigned T/M/S aircraft. Maintenance personnel priorities are to support flight crews and conduct required planned maintenance and unscheduled maintenance on assigned assets. The primary maintenance actions authorized at this level are limited to removal and replacement of fully assembled aircraft components. In other words, assigned maintenance personnel are not authorized to break the integrity of any installed components, only remove or replace them.

Consistent with the maintenance actions authorized at the O-level, there are three general scenarios in which electronic log-sets are updated and/or validated.

The first is when a discrepancy is identified on a component and authorized maintenance actions restore the part to FMC status without removal and replacement. In this scenario, the maintenance actions executed are updated to the log-set in OOMA NALCOMIS and no further action is required. The other instances requiring log-set update or validation arise when a degraded component must be removed and retrograded to higher echelon maintenance and a replacement part is ordered. In this case, log-set update and validation must occur for both the outgoing part upon transfer and the incoming part upon receipt.

The swim lane chart in Figure 4 provides an overview of the three scenarios and includes a description of actions performed across all sections of an O-level maintenance activity from initial degradation of an aircraft to restoration of FMC and RFT status. Each step in the process that requires electronic log-set updating or validation is annotated with a blue star. Individual steps in the process are explained in detail in the following paragraphs.

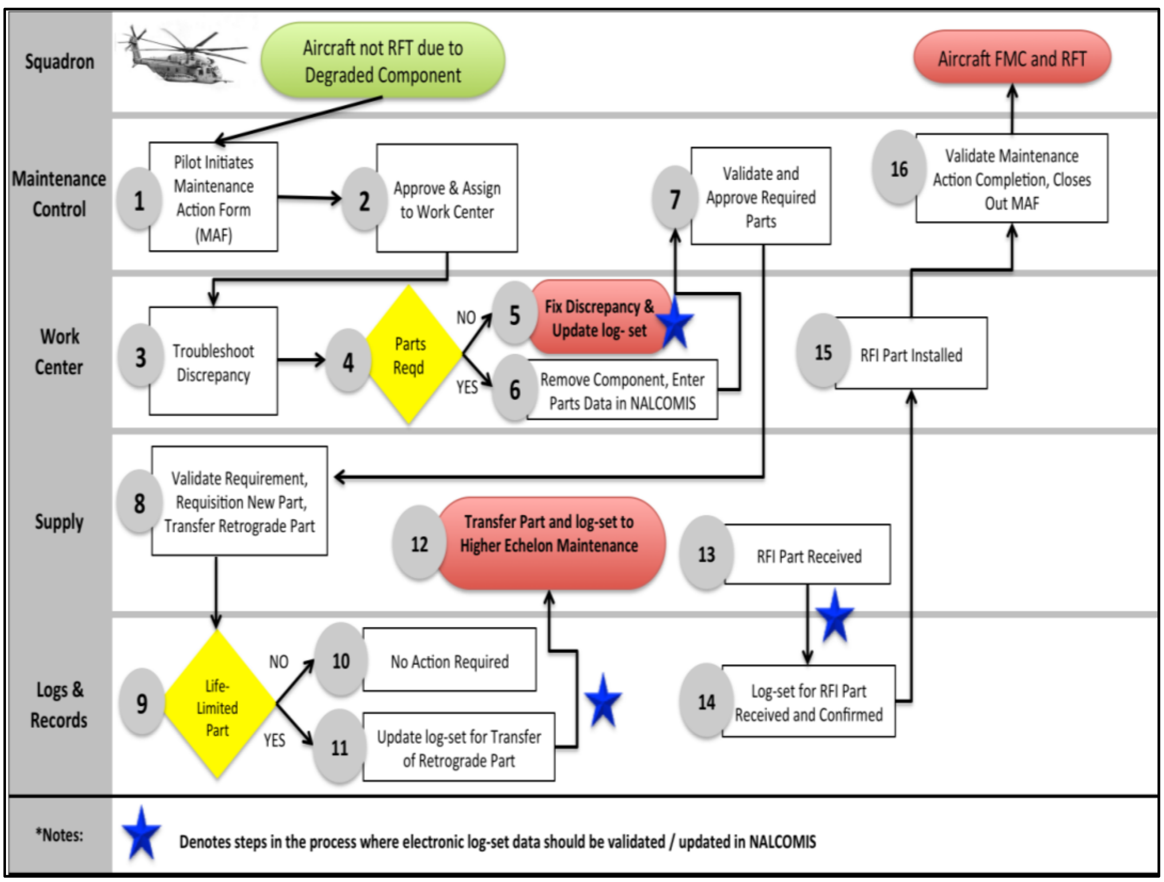

Figure 4. O-Level Maintenance Swim Lane Chart

Aircraft are complex, multifaceted systems that require planned and unplanned maintenance performed and supported by qualified personnel in order to maintain FMC status. As such, O-level maintenance activities are tasks organized

by functional area of expertise and coordinated to streamline the maintenance process whereby the time aircraft remain in NMC status is minimized. The four main functional areas in a typical O-level maintenance activity are Maintenance Control, Work Centers, Supply, and Logs and Records. Although there are several sub-sections beneath the four main functional areas also contributing to the overall maintenance effort, for the purpose of simplistically illustrating the flow of electronic log-sets during the maintenance process, only these four are illustrated in the swim lane chart.

Process Start: Aircraft Degraded

1. <u>Create maintenance action form (MAF).</u>

Upon completion of a flight or immediately following a flight cancellation, aircrew log into OOMA NALCOMIS and create an MAF regarding the system discrepancy discovered. Inputs include a description of capability lost, equipment name (if known), and any additional information that may provide assistance to the maintainers as to the cause of failure.

2. <u>Assign work center and begin maintenance approval process.</u>

Each MAF entered into OOMA NALCOMIS is assigned an identifier code known as a job control number (JCN), which links the maintenance action required to a sequenced event number for maintenance manager prioritization and tracking. Once the MAF is entered, Maintenance Control personnel authorized to approve maintenance actions review and validate the work to be performed and assign the maintenance action to the work center with the appropriate maintenance capability.

3. <u>Troubleshoot discrepancies.</u>

Work center personnel troubleshoot reported discrepancies and consult tech manuals and configuration data concerning the broken or degraded system to determine the cause of the system failure. In many cases, technicians utilize peculiar support equipment items to validate the root cause of the discrepancy with greater certainty.

4. <u>Determine whether parts are required.</u>

Following confirmation of the root cause of a discrepancy, technicians select the preferred course of action required to fix the system and determine whether replacement parts are required. Accordingly, they will either perform the maintenance action necessary to correct the issue or select the part(s) from the corresponding MIM.

5. Fix discrepancy and update log-set.

If no parts are required to correct the discrepancy, the work center technician executes the appropriate maintenance action and utilizes a test-and-check methodology to validate the component is back to FMC status. Once all maintenance actions are complete, the technician updates the electronic log-set in OOMA NALCOMIS, noting all maintenance performed.

6. Remove component and identify replacement part.

Work center personnel consult tech manuals and configuration data concerning the broken or degraded part that caused the aircraft failure. Once the correct part(s) required to fix the system are confirmed, the part(s) are selected from the corresponding system configuration database in OOMA NALCOMIS and requested under the appropriate MAF. OOMA NALCOMIS displays the current database of parts associated within a system as well as the quantity of consumable parts or repairable items personnel are authorized to order against a single repair action. This limits ordering capacity to meet actual demand and prevents work centers from stockpiling spare parts. In addition, OOMA NALCOMIS provides amplifying information on each item requested and classifies it as a D-level repairable or consumable item and identifies the location the component will be expedited from. This additional information allows maintenance managers to more accurately predict total aircraft downtime and provides the squadron commander with a realistic estimate of when the aircraft will be available and RFT.

7. Approve parts.

Managers within the Maintenance Control section of the O-level activity utilize OOMA NALCOMIS to review all documents placed on order against required maintenance actions. They screen orders for validity and apply the appropriate project priority code according to urgency of need, location of squadron operation, and type of component ordered. Following approval, the document number is transmitted to Supply for final validation and requisition.

8. Validate requisition.

Supply personnel monitor all materials ordered via OOMA NALCOMIS and subsequently validate all requisitions by verifying project priority codes, units of issue, and total cost to ensure proper fiscal accountability of required materials. Once a requisition is validated and approved, Supply places the order for the replacement parts. In conjunction with the requisition of the replacement parts, Supply also prepares the degraded component for retrograde to the appropriate higher echelon maintenance activity. Key to this process is close coordination with the Logs and Records section to ensure all required shipment and maintenance

paperwork for the degraded component accompanies it upon transfer—including the electronic log-set, if the component is life-limited.

9. Review logs and records.

Logs and Records personnel are contacted by Supply during the process of transferring components to ensure all required documentation is attached, including an electronic log-set if applicable. Logs and Records personnel verify the applicable T/M/S aircraft periodic maintenance information cards (PMIC) to validate whether the outgoing component has mandatory life-cycle tracking hard cards and/or electronic log-sets to transfer with the physical component.

10. Determine if component is not life-limited.

Verification of life-limited status of the component in the PMIC manual yields negative results and requires no further action from Logs and Records personnel.

11. Determine if component is life-limited.

Upon verification in the PMIC manual that the component is life-limited, the Logs and Records clerk updates and verifies the component's data within OOMA NALCOMIS and prepares the electronic log-set for transfer to the receiving maintenance activity. Additionally, the clerk must confirm the accuracy of life-cycle information recorded on the Scheduled Removal Component (SRC) card, Module Service Record (MSR), Equipment History Record (HER), and any other hard-copy record still required by the T/M/S PMIC manual. The life-cycle information contained on the hard-copy records must match the information contained in the electronic log-set in OOMA NALCOMIS prior to the physical transfer of the component and the electronic transfer of the log-set.

12. Execute physical transfer of component/electronic transfer of log-set.

Supply work center personnel execute the physical transfer of the retrograde component to the designated repair activity. At the time of shipment, Supply verifies Logs and Records personnel transmitted the electronic log-sets to the same designated repair activity awaiting receipt of the degraded component.

13. Receive replacement component.

Supply receives and takes physical custody of the requisitioned replacement component.

14. Confirm receipt of log-set.

Immediately following physical receipt of the replacement component by Supply, Logs and Records personnel are notified in order to confirm receipt of the electronic log-set and verify the currency and accuracy of the log-set information. In the event a log-set is either not received or lacks current/accurate information, the

log-set retrieval cycle is initiated. The replacement component cannot be installed on the degraded aircraft until a current and accurate electronic log-set is received and validated.

15. Install replacement component.

After the Logs and Records section validates the log-set, the replacement part is transferred from Supply to the appropriate work center for installation on the aircraft.

16. Validate maintenance action/closeout MAF.

Maintenance Control personnel validate completion of all maintenance actions, close out the MAF, and certify the aircraft as FMC and RFT.

D. INTERMEDIATE- AND DEPOT-LEVEL MAINTENANCE

I- and D-level maintenance activities are strategically located aboard Naval and Marine Corps Air Stations spanning the east and west coasts of the United States and resident within partner nations of the south Pacific. Across the NAE, I-level activities comprised of approximately 6,500 Marines and Sailors are integrated with nearly 11,500 D-level civilian personnel to form FRCs. Figure 5 provides an overview of the FRC locations and associated support detachments.

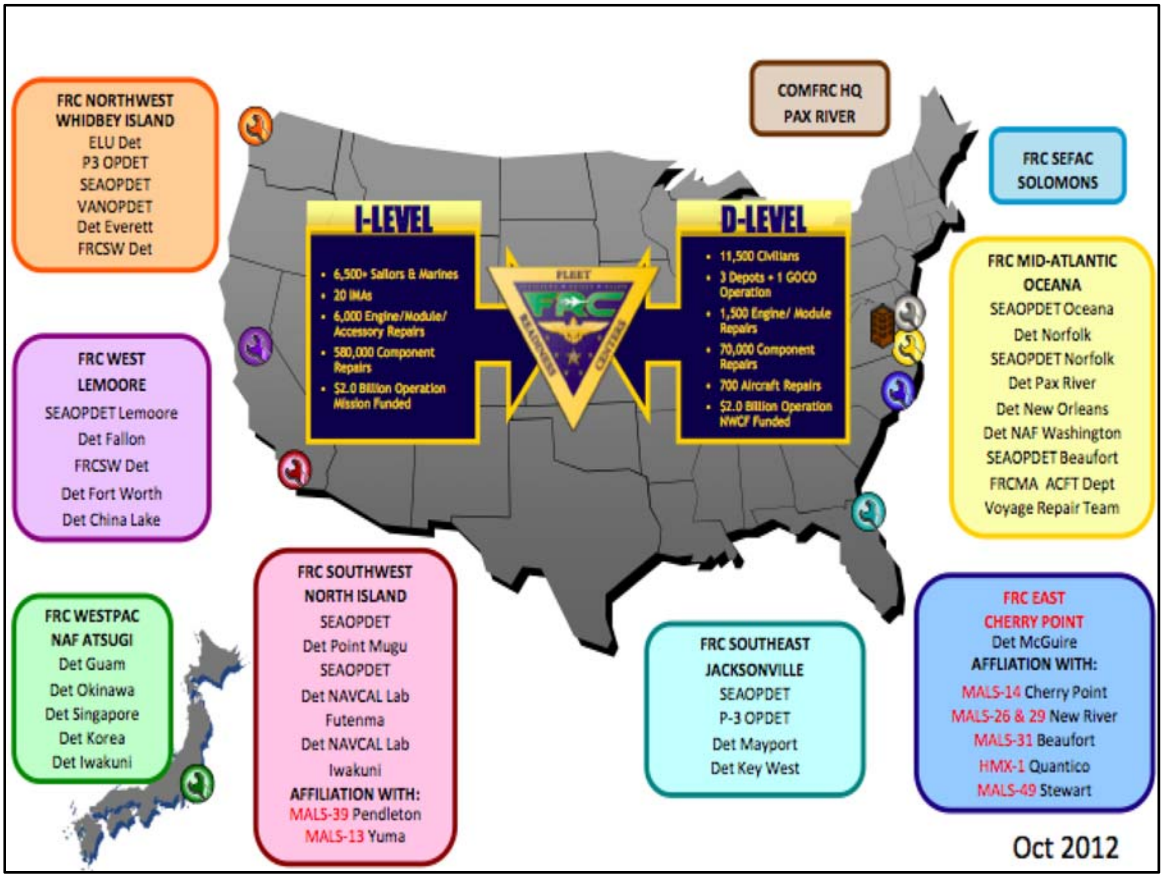

Figure 5. NAE Fleet Readiness Centers
(Paul, 2012)

In general, the FRCs provide higher echelon maintenance support to both home station and deployed O-level activities and associated operational squadrons across the NAE. Active duty service members at the I-level possess maintenance capabilities above those resident at the O-level, but must rely on the civilian employees from the D-level, known as *artisans,* for the most sophisticated and complex maintenance actions, such as tear-down and complete system overhaul. Some maintenance requirements may be so advanced and intricate that they exceed the capabilities of the D-level artisans, in which case, the component is sent to the original equipment manufacturer (OEM) for repair.

There are essentially two scenarios under which I- and D-level maintenance activities execute maintenance actions; these are planned and unplanned maintenance. Planned maintenance includes regularly scheduled periodic maintenance actions such as engine replacement or D-level overhaul. Unplanned maintenance includes emergent maintenance requirements resulting from conditions-based factors such as unforeseen degradation, excess operating hours, or harsh operating environments.

Whether required maintenance actions are planned or unplanned, or executed at the I- or D-level, the maintenance process begins with a degraded component or aircraft arriving at the FRC from an O-level activity. The swim lane chart in Figure 6 provides an overview of the maintenance process common in an FRC and includes a description of actions performed across all sections of an FRC maintenance activity from initial degradation of a component to FMC restoration and subsequent RFI status. Each step in the process that requires electronic log-set updating or validation is annotated with a blue star. Individual steps in the process are explained in detail in the following paragraphs.

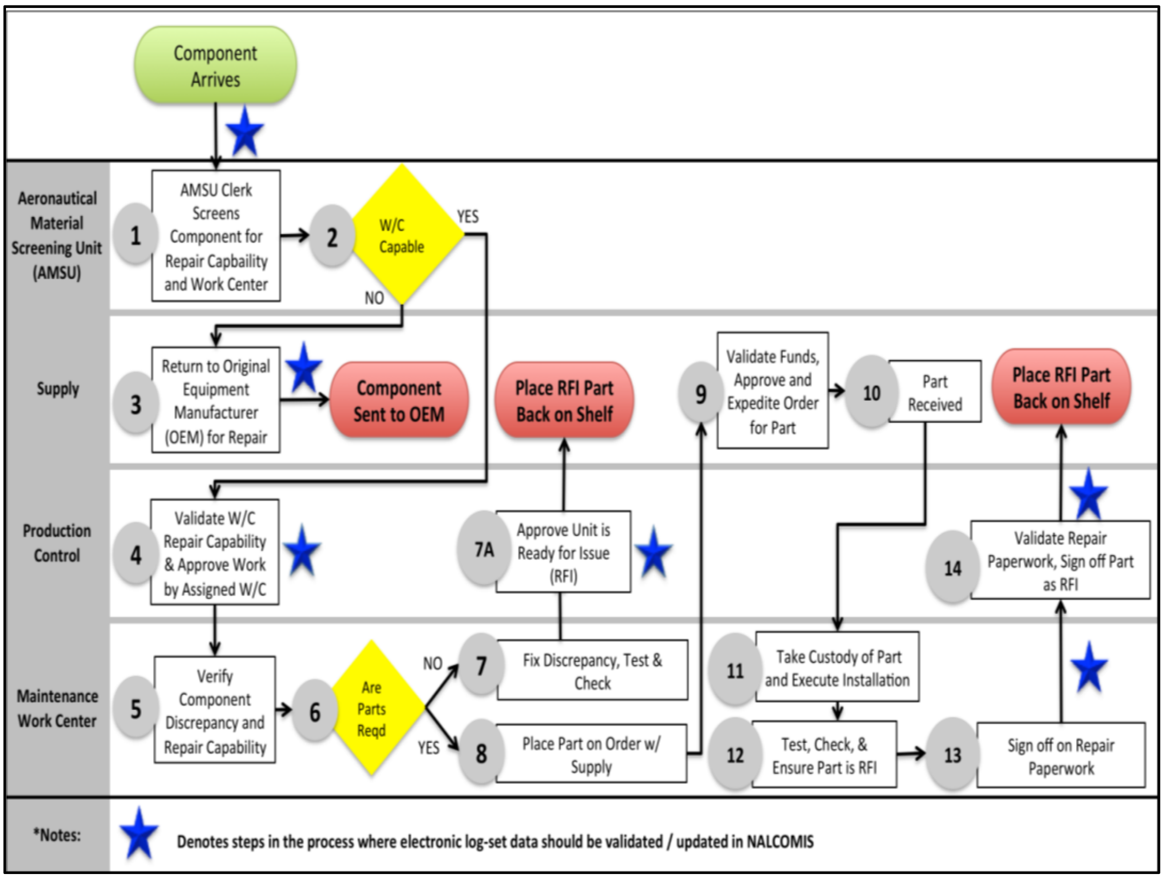

Figure 6. I- & D-Level Maintenance Swim Lane Chart

Similar to activities at the organizational level, I- and D-level maintenance activities are also tasks organized by functional area of expertise and coordinated to streamline the maintenance process whereby the time to execute maintenance and return RFI components or aircraft back to an O-level squadron is minimized. The four main functional areas in typical I- and D-level maintenance activities are the AMSU, Production Control, Work Centers, and Supply. Although there are several sub-sections beneath the four main functional areas also contributing to the overall maintenance effort, for the purpose of simplistically illustrating the flow of electronic

log-sets during the maintenance process, only these four are illustrated in the swim lane chart. Of note, the Logs and Records section that is recognized as a main functional area at the O-level is a sub-section of the Production Control functional area at the I- and D- levels.

Process Start: Degraded Component Arrives

When a component becomes degraded or inoperable at the O-level and is beyond the organic maintenance capability resident in house, the component is turned in to I-level or D-level for higher echelon repair.

1. Induct component process.

Upon arrival of a degraded component, the AMSU verifies the information on the hard-copy MAF matches the physical component received and also confirms receipt of the electronic log-set with the Logs and Records section within the Production Control Division.

2. Determine work center capability.

AMSU personnel conduct an OOMA NALCOMIS search using the part number of the component to access the Individual Component Repair Listing (ICRL) to determine if full, partial, or no repair capability exists at the I- or D-level and in which work center the capability resides. Subsequently, if the part number search yields a positive repair result, the AMSU clerk inducts the component into the maintenance cycle via the MAF loaded in OOMA NALCOMIS. The MAF is updated with the reason for induction (discrepancy), organization code of originating failure, and any additional amplifying information to help the technicians with troubleshooting the component.

3. Determine if maintenance required exceeds I- and D-level capability.

If the part number search executed by AMSU personnel yields a negative repair result, the clerk will mark the documentation as “X1” capability and in red three-inch letters annotate “beyond capability of maintenance” (BCM) to ensure proper transfer of the component back to the OEM for repair. Once the hard-copy documentation is updated, the component is turned over to Supply for outgoing shipment to the OEM.

Although the OEM very likely does not have OOMA NALCOMIS access or the capability to update the electronic log-set, it is essential for the Logs and Records clerks at the I- and D-level activities to ensure the log-set for the outgoing component is current and accurate so that when the component returns from the OEM, the log-set can be updated from the hard-copy paperwork that accompanies the return shipment.

4. <u>Approve maintenance and assign work center.</u>

Personnel in the Production Control (PC) Work Center function as the nerve center of the maintenance effort within the I- and D-level maintenance activities. After the AMSU validates the existence of maintenance capability for a degraded component, managers within PC review the induction document within OOMA NALCOMIS, approve the maintenance action, and assign the work to the appropriate work center for execution of all maintenance actions. During the approval process, PC managers assign priority codes to each component assigned to the work centers based on the urgency of need and basis of need dictated by the safety stock supply on hand.

5. <u>Validate discrepancies in the maintenance work center.</u>

Work center personnel troubleshoot reported discrepancies and consult tech manuals and configuration data concerning the broken or degraded system to determine the cause of the system failure. In many cases, technicians utilize peculiar support equipment items to validate the root cause of the discrepancy with greater certainty. Once technicians have validated the discrepancy utilizing supporting maintenance assistance modules, they either perform the maintenance function required to correct the issue or select the part(s) required from the corresponding MIM required to correct the discrepancy.

6. <u>Determine whether parts are required.</u>

Following confirmation of the root cause of a discrepancy, technicians select the preferred course of action required to fix the system and determine if replacement parts are required. Accordingly, they will either perform the maintenance action necessary to correct the issue or select the part(s) from the corresponding MIM.

7. <u>Execute maintenance when parts are not required.</u>

If no parts are required to correct the discrepancy, the work center technician executes the appropriate maintenance action and utilizes a test and check methodology to validate the component is back to FMC status. Once all maintenance actions are complete, the technician updates the electronic log-set in OOMA NALCOMIS, noting all maintenance performed, and forwards the component and any hard-copy paperwork to PC for final approval and electronic log-set update verification.

7a. <u>Certify component as RFI.</u>

Upon completion of maintenance actions by the work center, PC managers confirm all maintenance actions are complete and certify the component as RFI. Prior to placing the component back on the supply shelf for issue, Logs and

Records personnel ensure all maintenance actions performed are updated and correct on the electronic log-set in OOMA NALCOMIS. Once the log-set is verified, the component is placed back on the shelf for reissue.

8. Order required parts.

Just like at the O-level, work center personnel consult tech manuals and configuration data concerning the broken or degraded part. Once the correct part(s) required to fix the system are confirmed, the part(s) are selected from the corresponding system configuration database in OOMA NALCOMIS and requested under the appropriate MAF. The parts request is then certified by a PC manager and forwarded to Supply for requisition.

9. Validate requisition.

Also similar to the O-level, Supply personnel monitor all materials ordered via OOMA NALCOMIS and subsequently validate all requisitions by verifying project priority codes, units of issue, and total cost to ensure proper fiscal accountability of required materials. Once a requisition is validated and approved, Supply places the order for the replacement parts.

10. Receive repair parts.

Supply receives and takes physical custody of the requisitioned replacement parts.

11. Transfer repair parts to work center for installation.

Immediately following physical receipt of the repair parts at Supply, the parts are transferred to the applicable work center for installation.

12. Test, check, and certify.

After all maintenance actions are complete, technicians utilize test equipment and other assistance modules to simulate installation on an aircraft. Once the newly repaired component checks within tolerance, work center personnel certify the maintenance action as complete and declare the component RFI.

13. Update MAF and log-set.

Once the work center declares the component RFI, technicians document all maintenance actions on the hard-copy paperwork, update the MAF in OOMA NALCOMIS, and forward the component and documentation to PC for final verification and approval.

14. Validate life-cycle documentation and certify component as RFI.

Subsequent to the work center's completion of all maintenance actions, PC managers validate the work performed and Logs and Records personnel verify the

hard-copy records match the updated log-set in OOMA NALCOMIS. Once all verification is complete, PC managers certify the component as RFI, the MAF is closed out, and the component is placed back on the shelf for future issue to an O-level squadron.

VI. ANALYZING THE PROBLEM

A. DATA COLLECTION

The Aviation Logistics Division (ALD) within U.S. Marine Corps Forces Pacific (MARFORPAC) initiated the data sourcing for this project. The scope of data collection efforts targeted operational squadrons from the 1st Marine Air Wing (1st MAW) in Okinawa, Japan, and the 3rd Marine Air Wing (3rd MAW) in California and Arizona, as well as squadrons from both MAWs deployed to Afghanistan. Data collection efforts spanned a three-month period from June through August 2013 and resulted in a total of 204 observations.

The basic qualification parameter for data collection was any operational squadron that received an aircraft component from a higher echelon maintenance activity without the associated electronic log-set. The specific data collection fields included the following information:

- T/M/S aircraft
- part and serial number of the component
- activity the component was received from
- dates of OMAWHOLE and/or top tier query
- dates of query response and whether positive or negative
- length of time to update the log-set (if applicable)
- length of time to rebuild the log-set (if applicable)
- length of time the aircraft was NMC due to missing log-set

Once the data was received and consolidated, the times for updating and building log-sets as well as the time aircraft was NMC were converted into minutes to facilitate standardized presentation of the data results.

B. DATA ANALYSIS

1. Log-Set Query

The first set of data analyzed was the log-set query response time and the log-set query success rate. Essentially, upon receiving a component without the associated electronic log-set, squadrons were instructed to record the date of their log-set query to the OMAWHOLE repository and then record the date of response and whether the result was positive or negative. In this case, a “positive” result

meant that the log-set was found and could be updated as required, while a “negative” result indicated that the log-set could not be retrieved.

Following the progression of the query hierarchy, if a squadron received a negative response from the OMAWHOLE (and in some cases, even when they received a positive response), they would then query the top tier server in an attempt to locate the log-set. In the same manner as the OMAWHOLE query, squadrons were instructed to record the date of their log-set query to the top tier server and then record the date of response and whether the result was positive or negative.

Query response time across both servers was surprisingly fast, with the OMAWHOLE providing a same-day response 81% of the time and the top tier server eliciting a same-day response 97% of the time. In terms of query success rate, the OMAWHOLE produced a positive response just 8% of the time, and the top tier server was not much better at just a 10% positive log-set query result. Figures 7 and 8 provide a graphic illustration of the log-set query response times and success rates as just described.

Figure 7. Log-Set Query Response Time

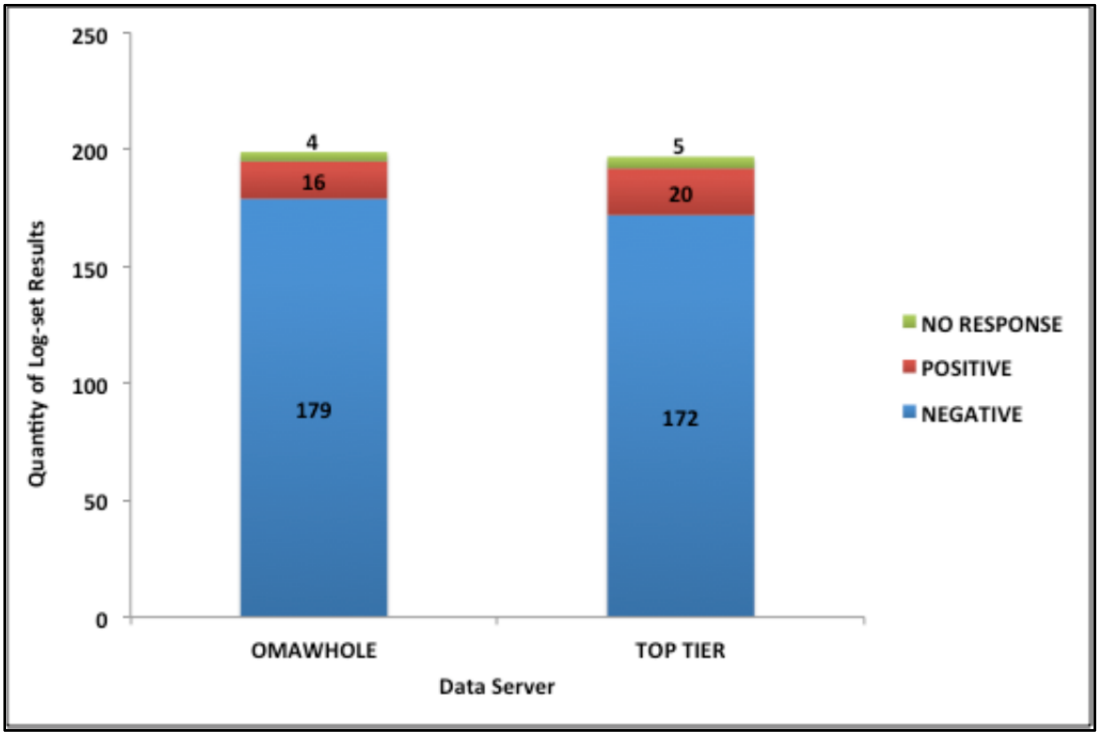

Figure 8. Log-Set Query Success Rate

2. Personnel Hours to Update or Build a Log-Set

When calculating the average amount of time (in minutes) required to either update or rebuild a log-set, we examined each one of the 204 observations to determine if there were any cases in which the amount of time recorded was zero. The data indicated there were 87 instances in which the time to update a log-set was recorded as zero and 25 observations where the time to rebuild a log-set was recorded as zero.

Although the data collected does not provide a reason for these responses recorded as zero, it is reasonable to conclude that in observations where the time to update a log-set was zero, the squadron had to fully rebuild the log-set and, thus, did not record any time to update. Likewise, in observations where the time to rebuild the log-set was recorded as zero, it is reasonable to deduce that the log-set could be updated, thus eliminating the need to rebuild it.

In order to provide the most accurate representation of average time to update or rebuild a log-set, we removed all observations where the time recorded was zero from the calculation. This left a total of 117 observations for updating log-sets and 179 for rebuilding. The breakdown of this data collection can be seen in Tables 1 and 2.

Table 1. Frequency of Occurrence for Requirement to Update a Log-Set

	TIME TO UPDATE A LOG-SET (IN MINUTES)							
SOURCE	**0**	**6**	**12**	**30**	**120**	**300**	**600**	**OBSERVATIONS**
DEPOT	24	40	16					80
OTHER	2	28			1			31
SUPPLY	61	16	11	3		1	1	93
TOTAL COUNT	87	84	27	3	1	1	1	204

Table 2. Frequency of Occurrence for Requirement to Rebuild a Log-Set

	TIME TO BUILD A LOG-SET (IN MINUTES)											
SOURCE	**0**	**3**	**6**	**12**	**15**	**18**	**24**	**30**	**60**	**120**	**1440**	**OBSERVATIONS**
DEPOT	5		57			1		15	1		1	80
OTHER			28					1	1	1		31
SUPPLY	20	1	46	15	6		4	1				93
TOTAL COUNT	25	1	131	15	6	1	4	17	2	1	1	204

Once observations noting zero as the time to update or rebuild a log-set were removed from the sample, the average time for updating and rebuilding was calculated for three separate categories based on the origin of the received aircraft component: depot (FRC), supply, or other. The location "other" may include the OEM or any other higher echelon maintenance activity providing components.

The average times to update a log-set were 7.71 minutes for components arriving from an FRC, 38.06 minutes for components received from Supply, and 9.93 minutes for components acquired from the other maintenance organizations. On average, the time required to rebuild a log-set for components received from an FRC was 30.8 minutes, from Supply was 9.25 minutes, and from other was 12.19 minutes.

Further data analysis revealed that for both updating and rebuilding log-sets, there was a small number of outliers, which were significantly magnifying the average times. Specifically, there were three observations where updating a log-set required more than 30 minutes and four observations where rebuilding a log-set required more than 30 minutes. Consequently, in an effort to quantify the magnitude of the outliers, the average times for updating and rebuilding log-sets were recalculated without the inclusion of the seven outlier observations. The results can be viewed in Figures 9 and 10.

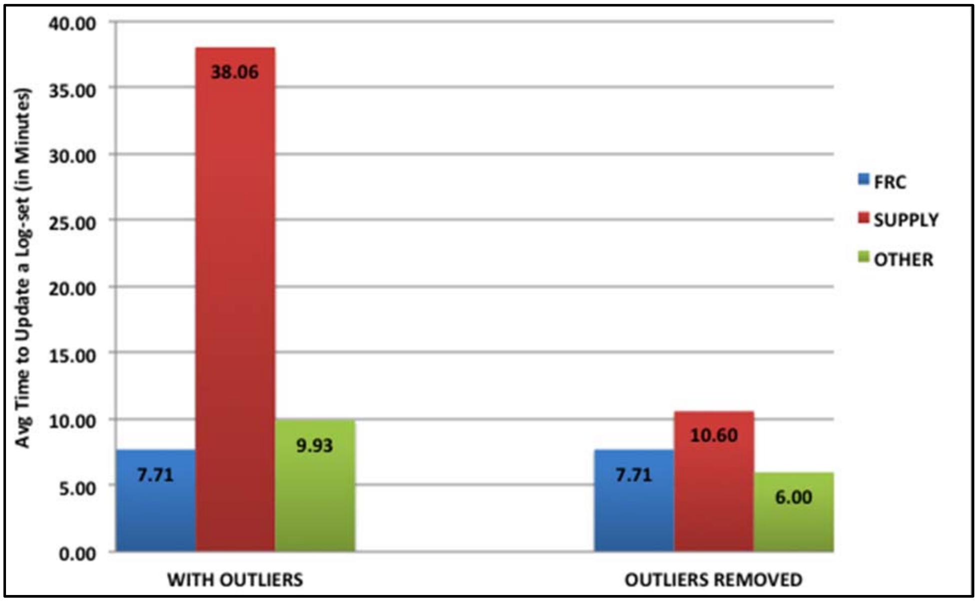

Figure 9. Average Time to Update a Log-Set

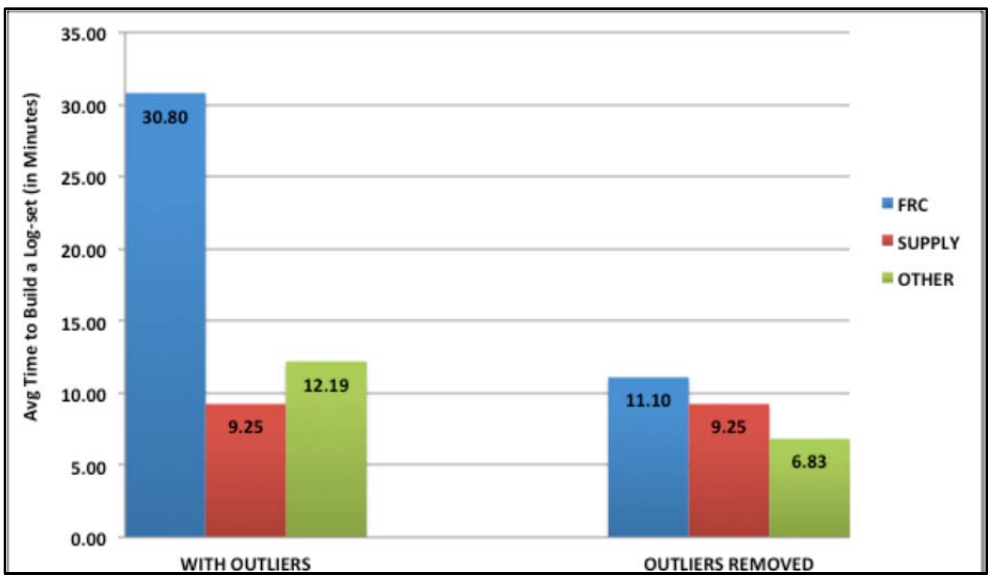

Figure 10. Average Time to Build a Log-Set

Analysis of the data graphically represented in these figures suggests that regardless of whether outliers are removed or included in the calculations, average time to update a log-set is greatest when the origin of the component is Supply. Conversely, average time to rebuild a log-set is greatest when the origin of the component is an FRC.

3. Personnel Cost to Update or Build a Log-Set

Utilizing the calculated average times for updating and rebuilding log-sets as described in the previous section, it was possible to estimate the personnel cost

associated with the log-set actions. Accordingly, the first step was to determine an appropriate cost factor to use in the calculations. To make this calculation, we used the Office of the Under Secretary of Defense (OUSD) memorandum *FY 2013 Department of Defense (DoD) Military Personnel Composite Standard Pay and Reimbursement Rates* dated April 9, 2012. From the OUSD memorandum, we used the U.S. Marine Corps annual composite rates in the calculations. Of note, "composite" rates include basic pay, basic allowance for housing, basic allowance for subsistence, incentive and special pay, permanent change of station expenses, and miscellaneous pay (OUSD, 2012).

To provide a fair estimate of the cost of updating and rebuilding log-sets, it was important to determine the average pay grade of the personnel performing log-set actions. As such, it was estimated that on average, personnel in the grades E-5 and E-6 would most likely be executing the update or rebuild of log-sets. Therefore, the FY 2013 annual composite rates for E-5 ($73,307) and E-6 ($90,139) were added together and averaged to arrive at an annual rate of $81,723.

Additionally, it was necessary to estimate the average number of work hours per week for each person so that an hourly wage rate and, ultimately, a wage rate per minute could be determined. For this purpose, we estimated 10-hour work days, five days per week for 52 weeks per year, which provided the average work hours per year of 2,600. Table 3 summarizes these calculations and displays the average earnings per minute rate of $0.52.

Table 3. Personnel Cost per Minute Conversion

Avg. Work Hours per Week	Weeks per Year	Avg. Work Hours per Year
50	52	2600
Average Salary of E-5 / E-6	**Earnings per Hour**	**Earnings per Minute**
$81,723	$31.43	**$0.52**

Once the personnel cost per minute was calculated at $0.52 as shown in Table 3, this table was used to calculate the personnel cost per log-set for both updating and rebuilding scenarios. Identical to the average time calculations, the three categories depot, Supply, and other were used to distinguish the origin of the aircraft component. Moreover, calculations were executed with outliers included and then with outliers removed to provide a complete picture of the effects of the outlier observations.

As shown in Figure 11, the average personnel cost to update a log-set is $4.04 when the component source is a FRC, $19.94 when sourced from Supply, and $5.20 when the component comes from an other organization. When outliers are

removed, personnel costs to update a log-set in each category are $4.04, $5.55, and $3.14, respectively.

Figure 12 displays the average personnel cost to rebuild a log-set is $16.14 when the component source is an FRC, $4.85 when sourced from Supply, and $6.39 when the component comes from an other organization. When outliers are removed, personnel cost to rebuild a log-set in each category are $5.81, $4.85, and $3.58, respectively.

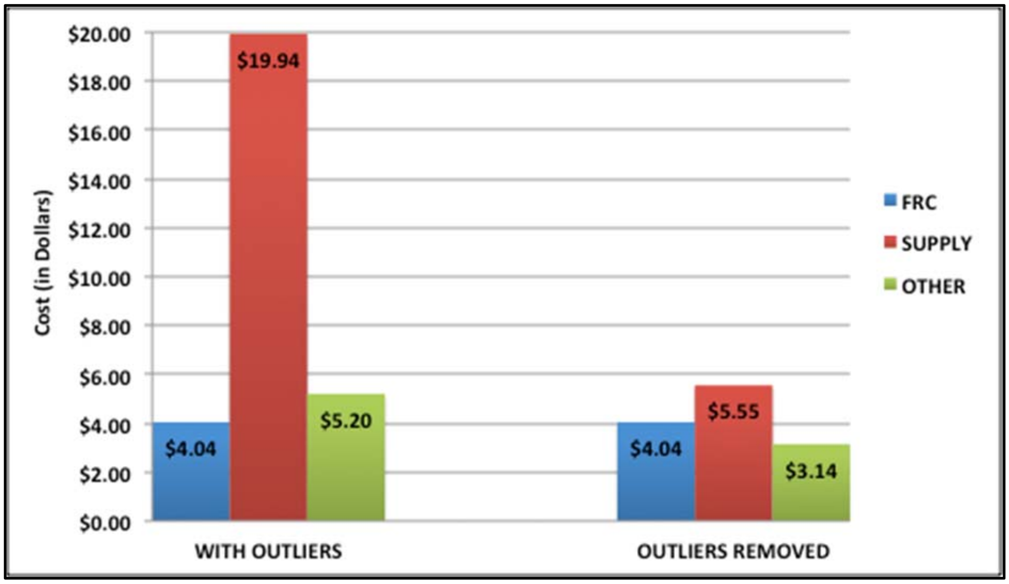

Figure 11. Personnel Cost to Update a Log-Set

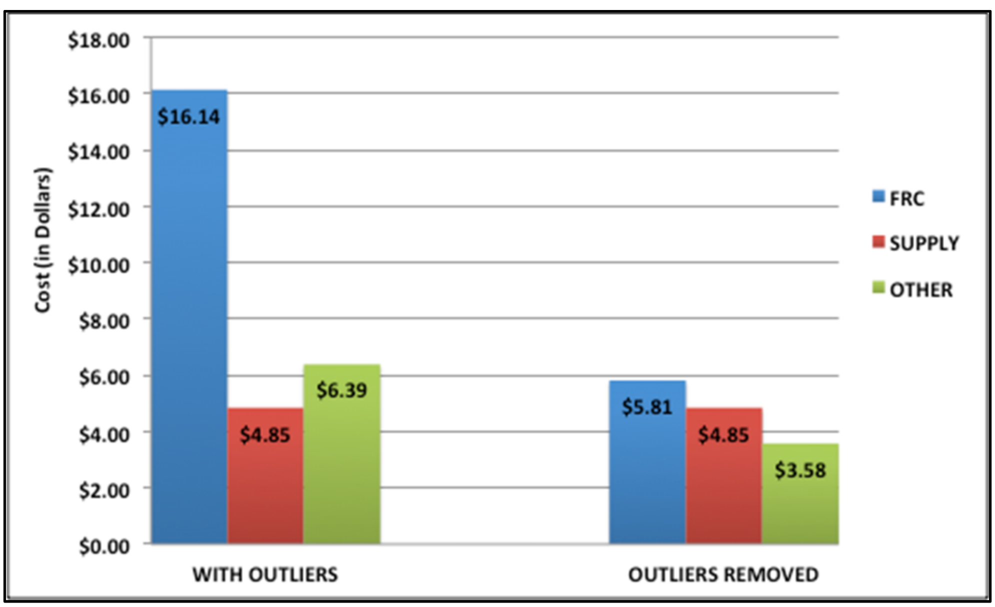

Figure 12. Personnel Cost to Rebuild a Log-Set

Consistent with the results of the average time to update and rebuild a log-set, analysis of the cost data represented in the figures suggests that regardless of whether outliers are removed or included in the calculations, average personnel cost to update a log-set is greatest when the origin of the component is Supply. Conversely, average personnel cost to rebuild a log-set is greatest when the origin of the component is an FRC.

4. Average Time Aircraft Is Non-Mission Capable

The final and perhaps most important analysis of the data was to determine the average amount of time an aircraft was rendered NMC due to a component arriving at a squadron without the electronic log-set. Initial analysis of the 204 observations revealed there were 56 instances in which the time an aircraft was NMC was recorded as zero. However, contrary to other calculations in this report where observations recorded as zero were excluded, instances of zero as the NMC time **were** utilized in these calculations as explained in the following paragraph.

The *NAMP* defines NMC as the "material condition of an aircraft that is not capable of performing any of its missions" (COMNAVAIRFOR, 2012, p. A-53). Consistent with the definition, it is reasonable to conclude that a degraded aircraft in which a component repair or replacement was delayed due to a missing log-set may still have the capability to perform its mission; thus, an NMC time of zero is justified. Consequently, all NMC times recorded as zero in the data set were included in the calculations.

Using the full sample of 204 observations, the average time an aircraft was NMC was calculated for three separate categories based on the origin of the received aircraft component: depot (FRC), Supply, or other. The average amount of time an aircraft was NMC was 125.25 minutes for components arriving from an FRC, 121.16 minutes for components received from Supply, and 104.52 minutes for components acquired from other maintenance organizations.

Similar to the outlier observations found in the data analysis previously discussed, there were also a small number of outliers recorded for time an aircraft was NMC, which significantly magnified the average times. Specifically, there were two observations where the time an aircraft was NMC exceeded 4,300 minutes. Consequently, in an effort to quantify the magnitude of the outliers, the average times an aircraft was NMC were recalculated without the inclusion of these two outlier observations. A graphical representation of the comparison is shown in Figure 13.

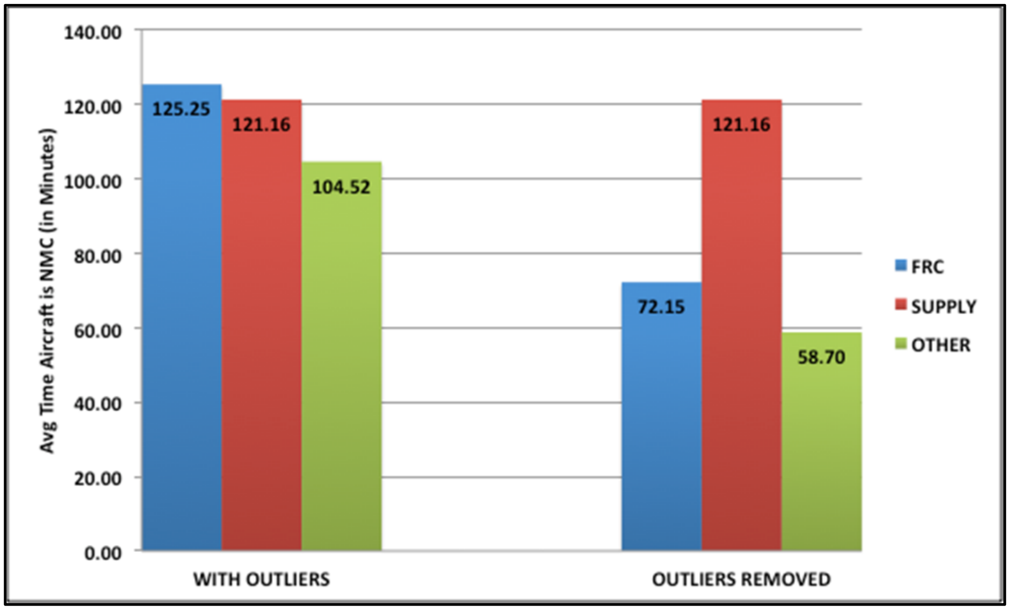

Figure 13. Average Time an Aircraft Is Non-Mission Capable

Analysis of the data represented in Figure 13 reveals that when outlier observations are included, components received from an FRC create the largest average NMC time for squadron aircraft. However, when outlier observations are removed from the calculation, components received from Supply create the largest average NMC time.

5. Linear Regression Analysis

Following analysis of average NMC time in terms of the origin of the replacement component as described in the previous section, we conducted a linear regression analysis to measure the statistical significance and the proportion of response variation explained by the independent variables in the model. The dependent variable in the model is time an aircraft is NMC, while the independent variables are the origin locations of the replacement components: FRC, Supply, and other. The results of the regression are shown in Table 4.

Table 4. Linear Regression Analysis

R	0.27162							
R Square	**0.07378**							
Adjusted R Square	0.06447							
S	273.22279							
Total # of observations	202							
Min NMC = 72.1519 * FRC + 58.6957 * SUPPLY + 121.1613 * OTHER								
ANOVA								
	d.f.	***SS***	***MS***	***F***	***p-level***			
Regression	3.	1,183,304.15	394,434.72	5.28	0.00159			
Residual	199.	14,855,487.85	74,650.69					
Total	202.	16,038,792.					***H0 (5%) rejected?***	
	Coefficients	***Standard Error***	***LCL***	***UCL***	***t Stat***	***p-level***		
Intercept	0							
FRC	72.1519	30.73997	11.53402	132.77	2.34717	**0.0199**	*Yes*	
SUPPLY	58.69565	28.48544	2.52359	114.87	2.06055	**0.04065**	*Yes*	
OTHER	121.16129	49.07226	24.39292	217.93	2.46904	**0.01439**	*Yes*	
T (5%)	1.97196							
LCL - Lower value of a reliable interval (LCL)								
UCL - Upper value of a reliable interval (UCL)								

As shown in the regression analysis results, the R Square of 0.07378 indicates that 7.3% of the variation in average time an aircraft is NMC is explained by the FRC, Supply, and other coefficients, i.e., by the source for the repair components. Additionally, the *p*-values for the FRC (0.0199), Supply (0.04065), and other (0.01439) indicate that all independent variables are statistically significant for the model.

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VII. IMPROVING AND CONTROLLING THE PROBLEM

A. INTRODUCTION TO IMPROVEMENTS

Based on insights captured during the define, measure, and analyze phases of the DMAIC framework, there are several areas where gains in efficiency are possible for the reduction of aircraft NMC time. Although personnel costs associated with updating and building log-sets were estimated, they are positive linear byproducts of the time requirement for each process and are not drivers of aircraft NMC time. Consequently, improvement recommendations for cost reduction are not discussed in this report. The following paragraphs provide an overview of the areas for improvement and outline actionable recommendations to achieve a potential decrease in aircraft NMC time.

B. IMPROVEMENT RECOMMENDATION 1

As presented in the analysis chapter, the data observations displaying log-set query response time as “same day” are 81% and 97% for OMAWHOLE and top tier servers, respectively, which indicates that this factor is not a significant driver of aircraft NMC time. In contrast, the low query success rates of below 10% yielded from the same-day responses most certainly contribute to the requirement to update or rebuild log-sets—processes the data indicates are contributors to aircraft NMC time.

Although the sample size was only 204 observations, the percentage of occurrences in which a log-set was rebuilt was much higher than anticipated at 87.7% (179/204). Interview responses from squadron personnel indicated that there were times when log-sets were rebuilt simply because it took less time to rebuild a log-set than to endure the research time required to update it. Also noted in several survey and interview responses was the fact that rebuilding a log-set creates a duplicate record in the repositories for the same component. Consequently, over time the repositories become clogged with duplicate records, which may result in false negative query responses.

Therefore, we recommend Logs and Records personnel at all maintenance activities avoid rebuilding log-sets to the extent possible and do so only as a last resort (i.e., in the case of a mission-critical flight requirement). Additionally, SPAWAR system administrators should initiate a fleet-wide effort to sanitize duplicate log-set records from NALCOMIS and associated repositories.

C. IMPROVEMENT RECOMMENDATION 2

According to the data sample, average time required to update log-sets was highest in cases where the component was sourced from Supply. Analysis of the

data by itself does not reveal a definitive reason for this outcome; however, based on interviews conducted at the O- and I-levels, there are two common issues that may be valid contributory factors.

The first issue is that the Logs and Records clerks fail to execute the transfer of the log-set in NALCOMIS prior to the physical transfer of the component. In cases where the I-level activity is located on the same flight line as the O-level activity receiving the part, the time required to walk over to the I-level and direct the Logs and Records clerk to transfer the log-set is likely minimal. However, in cases where the I-level activity is not located on the same installation, the time required to induce movement on the log-set transfer may be significantly longer. To remedy this issue, a standard operating procedure (SOP) with associated checklist should be created to direct the electronic transfer of the log-set to occur prior to the physical transfer of the component. Additionally, Logs and Records clerks should take a screenshot of the log-set transfer screen following execution and e-mail it to the squadron awaiting receipt of the component. Finally, to ensure the receipt of the e-mail, a phone call confirmation should be executed. This or a similar SOP that is understood, executed, and enforced would go a long way toward reducing the average time to update a log-set.

The second issue concerns components on the shelf at the I-level that were received from the D-level or OEM and have not been subsequently required by or issued to an O-level activity. Although Logs and Records clerks at the I-level should be verifying the electronic log-sets upon receipt of a component, if the part is not immediately transferred to an O-level squadron, it is possible that parts remain on the I-level shelves for weeks or months without a verified, updated log-set. Then once the part is required, the out-of-date log-set is discovered and the retrieval process may be much longer. Once again, we recommend mitigation through the establishment of an I-level SOP that not only directs Logs and Records clerks to confirm log-sets of all components received, but also mandates weekly spot checks of select parts on the shelf as well as monthly log-set verification of all components on hand.

D. IMPROVEMENT RECOMMENDATION 3

The data sample showed the average time required to rebuild log-sets was highest in cases where the component was sourced from the FRC. Analysis of the data by itself does not reveal a definitive reason for this outcome; however, based on interviews conducted at the D- and I-levels, there is one main issue which may be consistent with the data and reasonably considered as a valid contributory factor. FRC maintenance work centers are providing components to O- and I-level customers without updating the electronic log-set via NALCOMIS. Specifically, interview respondents reported log-sets are not updated throughout the repair

process due to the failure of civilian contractor personnel to use NALCOMIS on the repair lines because they are neither trained to operate the system nor required by contract to utilize it.

In order to rectify this issue, we recommend all future contracts negotiated with D-level artisan teams include a requirement to utilize NALCOMIS as the sole source for maintaining and updating repair records for all T/M/S aircraft and associated components. To that end, future contracts must also mandate a specific minimum percentage of D-level artisan team members be trained and proficient in NALCOMIS use—with the ultimate goal of 100% trained and fully proficient.

To bridge the gap for a short time in the interim, we recommend D-level work centers employ aviation maintenance administration (AZ) personnel or equivalent to facilitate compliance with all required log-set transfer and receipt responsibilities. To accomplish this, FRCs could absorb the AZ shortage via their I-level manning document, shifting personnel performing duties on the I-level side of FRC to fill in for the shortage on the D-level lines.

E. IMPROVEMENT RECOMMENDATION 4

Although the data itself does not justify causality, based on feedback from interview respondents at the O-, I-, and D-level maintenance activities, we believe there may be a link between the data collection results and the proficiency level of the Logs and Records clerks. Accordingly, we recommend periodic sustainment training of AZ personnel from all levels of maintenance to ensure optimal proficiency in updating, receipt, and transfer of electronic log-sets, as well as instruction on log-set research and retrieval procedures.

Additionally, units that have executed Lean Six Sigma, Rapid Improvement Events (RIEs) focused on streamlining processes, and procedures for electronic log-set management should share the results with the fleet so that a best practice repository may be built and unit SOPs tailored to the specific needs of any unit may be crafted.

F. CONTROLLING THE PROBLEM

Quite simply, the best and most effective way of controlling the problem is by aggressive management and vigilant enforcement of the policies and procedures outlined in the COMNAVAIRFORINST and other applicable directives. This may be achieved through quality assurance initiatives, spot checks, and establishment of a command climate across all maintenance activities that recognizes the importance of electronic log-set maintenance and strives to achieve it.

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VIII. RESEARCH LIMITATIONS AND RECOMMENDATIONS FOR FURTHER RESEARCH

A. RESEARCH LIMITATIONS

Many factors limited the scope and quality of our research effort, the largest of which was the relatively small sample size of the data. The original intent of the data collection effort was to gain a fair representation of the effects of missing log-sets on aircraft readiness over a broad range of T/M/S aircraft and across all aviation activities within MARFORPAC. Given that MARFORPAC supplies roughly two-thirds of the entire Marine Corps' air combat power, the data sample of only 204 observations from a total of seven squadrons was a major limiting factor in providing a comprehensive analysis.

Second, of the 204 data observations received, 86% (176/204) were for the CH-53E T/M/S aircraft, with the MV-22 representing the next highest total with just 14 (7%). All other T/M/S aircraft accounted for less than 7% of the total sample size. As a result, the conclusions from the analysis contained in this report are realistically limited to an adequate representation of the CH-53E community.

Next, some of the data inputs provided by the operational squadrons appeared to be best estimates rather than actual, calculated figures. For example, times reported for updating a log-set included 3, 6, 12, 15, 24, and 30 minutes—all multiples of three. There was not a single instance in which a recorded time was a fraction or seemed representative of an actual, carefully calculated time. Estimates reported in this manner seemed to devalue the true accuracy of the data and made it difficult to have a high degree of confidence in the integrity of the data.

Finally, the number of responses received from the anonymous online survey conducted was below 25, making it extremely difficult to identify trends and make any conclusions regarding potential fleet-wide representations of the effects of missing log-sets on aircraft readiness. Fortunately, the information garnered via face-to-face interviews at activities from all three maintenance levels proved invaluable in supplementing the survey responses to enable a slightly more complete assessment of potential causal factors.

B. RECOMMENDATIONS FOR FUTURE RESEARCH

The findings contained in this report provide a solid foundation from which to form additional, more comprehensive studies into the effects of missing electronic log-sets on aircraft readiness. First, future data collection efforts should be executed in the form of a MARFORPAC directive distributed via official naval message in order to achieve maximum input from the fleet. Within the directive, detailed

instructions regarding input data should be outlined to ensure all units submit data in the same format, using the same metrics, and with the same understanding of what is actually required in each block of the data collection spreadsheet. Similarly, dissemination of the solicitation for survey participation should be executed in the same manner, via official naval message, in order to achieve maximum exposure and yield a wide range of responses.

The site visits and on-site interviews conducted during this research represent O-, I-, and D-level activities from the southwestern United States only. For future research endeavors, it would be worthwhile to conduct site visits to activities in northern California, Arizona, Hawaii, and Japan in order gain better insight on local best practices and determine if commonality exists across all MARFORPAC activities.

Finally, in order to gain a comprehensive, total-force perspective into the magnitude of effects of missing log-sets on aircraft readiness, it would be wise to conduct similar data collection, site visits, surveys, and interviews at O-, I-, and D-level activities along the eastern United States. Following a Marine Corps-wide data collection effort and subsequent fleet-wide trends analysis, emerging best practices regarding log-set maintenance could be consolidated to facilitate a standardized SOP for the entire NAE.

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APPENDIX: SURVEY AND INTERVIEW QUESTIONS

1. Have you ever received a life-limited component from a supply or maintenance activity that did not contain the **required** electronic Configuration Management Automated Log-sets (CM ALS)?

   a. Yes b. No

2. If so, approximately how many times has this happened in the last 6 months?

   a. ______________________________

3. How much time does it take to remedy the missing electronic CM ALS issue so that the life-limited component could be installed on an aircraft?

   a. ______________________________

4. What is the procedure to remedy the problem? Contacted:

   a. OMAWHOLE b. Supply c. FRC d. Created new shell CM ALS

   e.____
   ____
   ____
   ____

5. At any time, did the missing electronic CM ALS lead to a flight delay or cancellation?

   a. Yes b. No

6. Did the missing electronic CM ALS lead to the unplanned cannibalization of another aircraft to maintain squadron readiness?

   a. Yes b. No

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